PB84-120641

Electric Arc Furnaces and Argon-Oxygen Decarburization Vessels in Steel Industry: Background Information for Proposed Revisions to Standards

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Jul 83

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA 450/3-82-020a

2.

3. RECIPIENT'S ACCESSION NO.
PB8 4 120641

4. TITLE AND SUBTITLE
Electric Arc Furnaces and Argon-Oxygen Decarburization Vessels in the Steel Industry--Background Information for Proposed Revisions to Standards

5. REPORT DATE
July 1983

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
68-02-3059

12. SPONSORING AGENCY NAME AND ADDRESS
Director for Air Quality Planning and Standards
Office of Air, Noise, and Radiation
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

13. TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE
EPA/200/04

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Standards of Performance for the control of emissions from electric arc furnaces and argon-oxygen decarburization vessels in the steel industry are being proposed under authority of Section 111 of the Clean Air Act. These standards would apply to those new, reconstructed, or modified electric arc furnaces and argon-oxygen decarburization vessels that commence construction on or after the date of proposal of the regulations. This document contains background information and environmental and economic impact assessments of the regulatory alternatives considered in developing the proposed standards.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air pollution Pollution control Standards of performance Steel plants Electric arc furnaces Argon-oxygen decarburization vessels	Air pollution control	

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 437
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/3-82-020a
July 1983

PB84-120641

Air

EPA

Electric Arc Furnaces and Argon-Oxygen Decarburization Vessels in Steel Industry — Background Information for Proposed Revisions to Standards

Draft EIS

NSPS

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NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

EPA-450/3-82-020a

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Emission Standards and Engineering Division

U.S ENVIRONMENTAL PROTECTION AGENCY
Office of Air Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

July 1983

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ENVIRONMENTAL PROTECTION AGENCY

Background Information and Draft Environmental Impact Statement for Electric Arc Furnaces and Argon-Oxygen Decarburization Vessels in the Steel Industry

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8/4/83
(Date)

1. The proposed standards of performance would limit emissions of particulate matter from new, modified, and reconstructed electric arc furnaces and argon-oxygen decarburization vessels in the steel industry. Section 111 of the Clean Air Act (42 U.S.C. 7411) as amended, directs the Administrator to establish standards of performance for any category of new stationary source of air pollution that ". . . causes or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."

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   Springfield, Va. 22161

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1. SUMMARY

1.1 REGULATORY ALTERNATIVES

Standards of performance for new stationary sources are developed under Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended. Section 111 requires the establishment of standards of performance for any new stationary source which ". . . causes, or contributes significantly to air pollution which causes or contributes to the endangerment of public health or welfare." The Act requires standards of performance for such sources to ". . . reflect the degree of emission limitation and the percentage reduction achievable through application of the best technological system of continuous emission reduction which (taking into consideration the cost of achieving such emission reduction, any nonair quality health and environmental impact, and energy requirements) the Administrator determines has been adequately demonstrated." The standards apply only to stationary sources, the construction, modification, or reconstruction of which starts after regulations are proposed in the Federal Register.

Three regulatory alternatives were selected for study. The first alternative would require no additional Federal regulatory action. The existing new source performance standards (NSPS) for electric arc furnaces (EAF's) would be applicable to new, modified, or reconstructed EAF sources and only State and local regulations would be applicable to new, modified, or reconstructed argon-oxygen decarburization (AOD) vessel sources. This alternative is considered to be the baseline condition from which the impacts of the other alternatives are calculated. The second and third alternatives would require Federal regulatory action and would place a more stringent limitation on the allowable levels of particulate matter and visible emissions than that allowed by the baseline condition. The same emission control systems are used for the second and third altneratives as for the first, but improvements in the emission capture systems would be required.

1.2 ENVIRONMENTAL IMPACT

The beneficial and adverse environmental impacts associated with each regulatory alternative over the baseline levels for the carbon and specialty steel shops are summarized in Table 1-1. As shown, a moderate-to-large beneficial air impact would result from adoption of Regulatory Alternative 2 or 3, and solid wastes would increase negligibly. The percent increase in solid wastes is the same for both the carbon and specialty steel shops. A modest increase in the energy requirements is also indicated under Regulatory Alternative 3. There would be no water or noise impacts. A matrix of the environmental and economic impacts for the regulatory alternatives is presented in Table 1-2.

1.3 ECONOMIC IMPACT

Capital and annualized costs were estimated for the regulatory alternatives. The capital and the annualized costs in the fifth year for the capture and control systems in the carbon and specialty steel shops under Regulatory Alternatives 2 and 3 show an increase from the baseline levels. These increases in the capital and annualized costs are the result of higher costs for the control and capture systems, which offset the decrease in the costs related to the use of periodic observation of emission capture systems operating parameters and of the opacity of visible emissions discharged from the pollution control device installed on the EAF or AOD vessel in lieu of continuous flow monitoring and of continuous opacity monitoring.

Cost impacts on product prices are generally quite small for the regulatory alternatives. Compared to Regulatory Alternative 1, Regulatory Alternative 2 would result in an increase of about 0.11 percent in the average total cost of producing carbon and specialty steel billets. The impacts of Regulatory Alternative 3 on average total cost of producing carbon and specialty steel billets are all under $1.90 per megagram (Mg). Regulatory Alternative 3 would result in a worst-case product price increase

TABLE 1-1. ENVIRONMENTAL AND ECONOMIC IMPACTS OF VARIOUS ALTERNATIVES COMPARED TO ALTERNATIVE 1 (BASELINE) IN THE FIFTH YEAR (1987)

Reg. alt.	Emission reduction			Solid waste increase			Energy increase		Cost increase[a]	
	Mg/yr	(tons/yr)	Percent	Mg/yr	(tons/yr)	Percent	kWh/yr	Percent	Capital, $	Annualized, $
					Carbon steel					
2	760	(850)	48	760	(850)	1	No increase	--	2,750,000	436,000
3	1,530	(1,690)	96	1,530	(1,690)	2	5.5×10^6	1.5	5,300,000	1,187,000
					Specialty Steel					
2	100	(110)	48	100	(110)	1	No increase	--	400,000	43,000
3	200	(220)	96	200	(220)	2	1.1×10^6	2.7	1,340,000	268,000

[a] Costs are reported in March 1981 dollars.

TABLE 1-2. MATRIX OF ENVIRONMENTAL AND ECONOMIC IMPACTS FOR REGULATORY ALTERNATIVES

Regulatory alternative	Air impact	Water impact	Solid waste impact	Energy impact	Noise impact	Economic impact
1	0	0	0	0	0	0
2	+3**	0	-1**	0	0	-1**
3	+4**	0	-1**	-1**	0	-2**

Key:	
+	Beneficial impact
-	Adverse impact
0	No impact
1	Negligible impact
2	Small impact
3	Moderate impact
4	Large impact
*	Short-term impact
**	Long-term impact
***	Irreversible impact

of approximately 0.32 percent, including monitoring costs. There would be no significant effect on the growth of the carbon and specialty steel shops.

2. INTRODUCTION

2.1 BACKGROUND AND AUTHORITY FOR STANDARDS

Before standards of performance are proposed as a Federal regulation, air pollution control methods available to the affected industry and the associated costs of installing and maintaining the control equipment are examined in detail. Various levels of control based on different technologies and degrees of efficiency are expressed as regulatory alternatives. Each of these alternatives is studied by EPA as a prospective basis for a standard. The alternatives are investigated in terms of their impacts on the economics and well-being of the industry, the impacts on the national economy, and the impacts on the environment. This document summarizes the information obtained through these studies so that interested persons will be able to see the information considered by EPA in the development of the proposed standards.

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 U.S.C. 7411) as amended, hereafter referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution which ". . . causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare."

The Act requires that standards of performance for stationary sources reflect ". . . the degree of emission limitation and the percentage reduction achievable through application of the best technological system of continuous emission reduction which (taking into consideration the cost of achieving such emission reduction, any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated." The standards apply only to stationary sources, the construction or modification of which commences after the standards are proposed in the Federal Register.

The 1977 amendments to the Act altered or added numerous provisions which apply to the process of establishing standards of performance. For example:

1. EPA is required to list the categories of major stationary sources which have not already been listed and regulated under standards of performance. Regulations must be promulgated for these new categories on the following schedule:

    a. 25 percent of the listed categories by August 7, 1980
    b. 75 percent of the listed categories by August 7, 1981
    c. 100 percent of the listed categories by August 7, 1982

A governor of a State may apply to the Administrator to add a category which is not on the list or may apply to the Administrator to have certain standards of performance revised.

2. EPA is required to review the standards of performance every 4 years and, if appropriate, revise them.

3. EPA is authorized to promulgate standards based on design, equipment, work practice, or operational procedures when standards based on emission levels are not feasible.

4. The term "standards of performance" is redefined, and a new term, "technological system of continuous emission reduction," is defined. The new definitions clarify that the control system must be continuous and may include a low- or nonpolluting process or operation.

5. The time between the proposal and promulgation of standards under Section 111 of the Act is extended to 6 months.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, taking into consideration the cost of achieving such emission reduction, any nonair quality health and environmental impact and energy requirements.

Congress had several reasons for including these requirements. First, standards having a degree of uniformity are needed to avoid situations where some States may attract industries by relaxing standards relative to other States. Second, stringent standards enhance the potential for long-term growth. Third, stringent standards may help achieve long-term cost savings by avoiding the need for more expensive retrofitting when pollution ceilings may be reduced in the future. Fourth, certain types of standards for coal-burning sources can adversely affect the coal market by driving up the price of low-sulfur coal or by effectively excluding certain coals from the reserve base due to their high untreated pollution potentials. Congress does not intend that new source performance standards contribute to these problems. Fifth, the standard-setting process should create incentives for improving technology.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. States are free under Section 116 of the Act to establish even more stringent emission limits than those established under Section 111 or than those necessary to attain or maintain the National Ambient Air Quality Standards (NAAQS) under Section 110. Thus, new sources may in some cases be subject to State limitations that are more stringent than standards of performance under Section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area that falls under the prevention of significant deterioration of air quality provisions of Part C of the Act. These provisions require, among other things, that major emitting facilities to be constructed in such areas are to be subject to best available control technology. The term "best available control technology" (BACT), as defined in the Act, means

> . . . an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from or which results from any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of each such pollutant. In no event shall application

> of "best available control technology" result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard established pursuant to Sections 111 or 112 of this Act. (Section 169(3))

Although standards of performance are normally structured in terms of numerical emission limits where feasible, alternative approaches are sometimes necessary. In some cases, physical measurement of emissions from a new source may be impractical or exorbitantly expensive. Section 111(h) provides that the Administrator may promulgate a design or equipment standard in those cases where it is not feasible to prescribe or enforce a standard of performance. For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling. The nature of the emissions (i.e., high concentrations for short periods during filling and low concentrations for longer periods during storage) and the configuration of storage tanks make direct emission measurement impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

In addition, under Section 111(j) the Administrator may, with the consent of the Governor of the State in which a source is to be located, grant a waiver of compliance to permit the source to use an innovative technological system or systems of continuous emission reduction. In order to grant the waiver, the Administrator must find that: (1) the proposed system has not been adequately demonstrated; (2) the proposed system will operate effectively and there is a substantial likelihood that the system will achieve greater emission reductions than the otherwise applicable standards require or at least an equivalent reduction at lower economic, energy, or nonair quality environmental cost; (3) the proposed system will not cause or contribute to an unreasonable risk to public health, welfare, or safety; and (4) the waiver when combined with other similar waivers, will not exceed the number necessary to achieve conditions (2) and (3) above. A waiver may have conditions attached to ensure the source will not prevent attainment of any National Ambient Air Quality Standard (NAAQS). Any such condition will be treated as a performance standard. Finally, waivers have definite end dates and may be terminated earlier if the conditions are not met or if the system fails to perform as expected. In such a case, the source may be given up to 3 years to meet the standards and a mandatory compliance schedule will be imposed.

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Administrator to list categories of stationary sources. The Administrator ". . . shall include a category of sources in such list if in his judgment it causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare." Proposal and promulgation of standards of performance are to follow.

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of an approach for assigning priorities to various source categories. The approach specifies areas of interest by considering the broad strategy of the Agency for implementing the Clean Air Act. Often, these areas are pollutants that are emitted by stationary sources rather than the stationary sources themselves. Source categories that emit these pollutants were evaluated and ranked considering such factors as: (1) the level of emission control (if any) already required by State regulations; (2) estimated levels of control that might be required from standards of performance for the source category; (3) projections of growth and replacement of existing facilities for the source category; and (4) the estimated incremental amount of air pollution that could be prevented in a preselected future year by standards of performance for the source category. Sources for which new source performance standards were promulgated or under development during 1977, or earlier, were selected using these criteria.

The Act amendments of August 1977 establish specific criteria to be used in determining priorities for all source categories not yet listed by EPA. These are: (1) the quantity of air pollutant emissions which each such category will emit, or will be designed to emit; (2) the extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare; and (3) the mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source standards of performance.

The Administrator is to promulgate standards for these categories according to the schedule referred to earlier.

In some cases, it may not be immediately feasible to develop standards for a source category with a high priority. This might happen if a program of research is needed to develop control techniques or if techniques for sampling and measuring emissions require refinement. In the developing of standards, differences in the time required to complete the necessary investigation for different source categories must also be considered. For example, substantially more time may be necessary if numerous pollutants must be investigated from a single source category. Further, even late in the development process the schedule for completion of a standard may change. For example, inability to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling. Nevertheless, priority ranking is, and will continue to be, used to establish the order in which projects are initiated and resources assigned.

After the source category has been chosen, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution, and emissions from these facilities may vary according to magnitude and control cost. Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there is no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by standards of performance, not all pollutants or facilities within that source category may be covered by the standards.

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must: (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost, the nonair quality health and environmental impacts, and the energy requirements of such control; (3) be applicable to existing sources that are modified or reconstructed as well as to new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

The objective of a program for development of standards is to identify the best technological system of continuous emission reduction that has been adequately demonstrated. The standard-setting process involves three principal phases of activity: (1) information gathering; (2) analysis of the information; and (3) development of the standard of performance.

During the information gathering phase, industries are questioned through telephone surveys, letters of inquiry, and plant visits by EPA representatives. Information is also gathered from other sources, including a literature search. Based on the information acquired about the industry, EPA selects certain plants at which emission tests are conducted to provide reliable data that characterize the pollutant emissions from well-controlled existing facilities.

In the second phase of a project, the information about the industry and the pollutants emitted is used in analytical studies. Hypothetical "model plants" are defined to provide a common basis for analysis. The model plant definitions, national pollutant emission data, and existing State regulations governing emissions from the source category are then used in establishing "regulatory alternatives." These regulatory alternatives are essentially different levels of emission control.

EPA conducts studies to determine the impact of each regulatory alternative on the economics of the industry and on the national economy, on the environment, and on energy consumption. From several alternatives, EPA selects the single most plausible regulatory alternative as the basis for standards of performance for the source category under study.

In the third phase of a project, the selected regulatory alternative is translated into performance standards, which, in turn, are written in the form of a Federal regulation. The Federal regulation, when applied to newly constructed plants, will limit emissions to the levels indicated in the selected regulatory alternative.

As early as is practical in each standard-setting project, EPA representatives discuss the possibilities of a standard and the form it might take with members of the National Air Pollution Control Techniques Advisory Committee. Industry representatives and other interested parties also participate in these meetings.

The information acquired in the project is summarized in the background information document (BID). The BID, the standard, and a preamble explaining the standard are widely circulated to the industry being considered for control, environmental groups, other government agencies, and offices within EPA. Through this extensive review process, the points of view of expert reviewers are taken into consideration as changes are made to the documentation.

A "proposal package" is assembled and sent through the offices of EPA assistant administrators for concurrence before the proposed standard is officially endorsed by the EPA Administrator. After being approved by the EPA Administrator, the preamble and the proposed regulation are published in the Federal Register.

As part of the Federal Register announcement of the proposed regulation, the public is invited to participate in the standard-setting process. EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standard with interested parties. All public comments are summarized and incorporated into a second volume of the BID. All information reviewed and generated in studies in support of the standard of performance is available to the public in a "docket" on file in Washington, D.C.

Comments from the public are evaluated, and the standard of performance may be altered in response to the comments.

The significant comments and EPA's position on the issues raised are included in the "preamble" of a promulgation package, which also contains the draft of the final regulation. The regulation is then subjected to another round of review and refinement until it is approved by the EPA Administrator. After the Administrator signs the regulation, it is published as a "final rule" in the Federal Register.

2.4 CONSIDERATION OF COSTS

Section 317 of the Act requires an economic impact assessment with respect to any standard of performance established under Section 111 of the Act. The assessment is required to contain an analysis of: (1) the costs of compliance with the regulation, including the extent to which the cost of compliance varies depending on the effective date of the regulation and the development of less expensive or more efficient methods of compliance; (2) the potential inflationary and recessionary effects of the regulation; (3) the effects the regulation might have on small business with respect to competition; (4) the effects of the regulation on consumer costs; and (5) the effects of the regulation on energy use. Section 317 requires that the economic impact assessment be as extensive as practicable.

The economic impact of a proposed standard upon an industry is usually addressed both in absolute terms and by comparison with the control costs that would be incurred as a result of compliance with typical, existing State control regulations. An incremental approach is taken because both new and existing plants would be required to comply with State regulations in the absence of a Federal standard of performance. This approach requires a detailed analysis of the economic impact of the cost differential that would exist between a proposed standard of performance and the typical State standard.

Air pollutant emissions may cause water pollution problems, and captured potential air pollutants may pose a solid waste disposal problem. The total environmental impact of an emission source must, therefore, be analyzed and the costs determined whenever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made for proposed standards. It is also essential to know the capital requirements for pollution control systems already placed on plants so that the additional capital requirements necessitated by these Federal standards can be placed in proper perspective. Finally, it is necessary to assess the availability of capital to provide the additional control equipment needed to meet the standards of performance.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 requires Federal agencies to prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decision-making process of Federal agencies a careful consideration of all environmental aspects of proposed actions.

In a number of legal challenges to standards of performances for various industries, the United States Court of Appeals for the District of Columbia Circuit has held that environmental impact statements need not be prepared by the Agency for proposed actions under Section 111 of the Clean Air Act. Essentially, the Court of Appeals has determined that the best system of emission reduction requires the Administrator to take into account counterproductive environmental effects of proposed standards, as well as economic costs to the industry. On this basis, therefore, the Courts established a narrow exemption from NEPA for EPA determinations under Section 111.

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to Section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969." (15 U.S.C. 793(c)(1))

Nevertheless, the Agency has concluded that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, although not legally required to do so by Section 102(2)(C) of NEPA, EPA has adopted a policy requiring that environmental impact statements be prepared for various regulatory actions, including standards of performance developed under Section 111 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, a separate section is included in this document which is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are discussed.

2.6 IMPACT ON EXISTING SOURCES

Section 111 of the Act defines a new source as ". . . any stationary source, the construction or modification of which is commenced . . ." after the proposed standards are published. An existing source is redefined as a new source if "modified" or "reconstructed" as defined in amendments to the General Provisions (40 CFR Part 60, Subpart A), which were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Promulgation of standards of performance requires States to establish standards of performance for existing sources in the same industry under Section 111(d) of the Act if the standard for new sources limits emissions of a designated pollutant (i.e., a pollutant for which air quality criteria have not been issued under Section 108 or which has not been listed as a hazardous pollutant under Section 112). If a State does not act, EPA must establish such standards. General procedures for control of existing sources under Section 111(d) were promulgated on November 17, 1975, as Subpart B of 40 CFR Part 60 (40 FR 53340).

2.7 REVISION OF STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, Section 111 of the Act provides that the Administrator ". . . shall, at least every 4 years, review and, if appropriate, revise . . ." the standards. Revisions are made to ensure that the standards continue to reflect the best systems that become available in the future. Such revisions will not be retroactive but will apply to stationary sources constructed or modified after the proposal of the revised standards.

3. ELECTRIC ARC FURNACES AND ARGON-OXYGEN DECARBURIZATION VESSELS IN THE STEEL INDUSTRY: PROCESSES AND POLLUTANT EMISSIONS

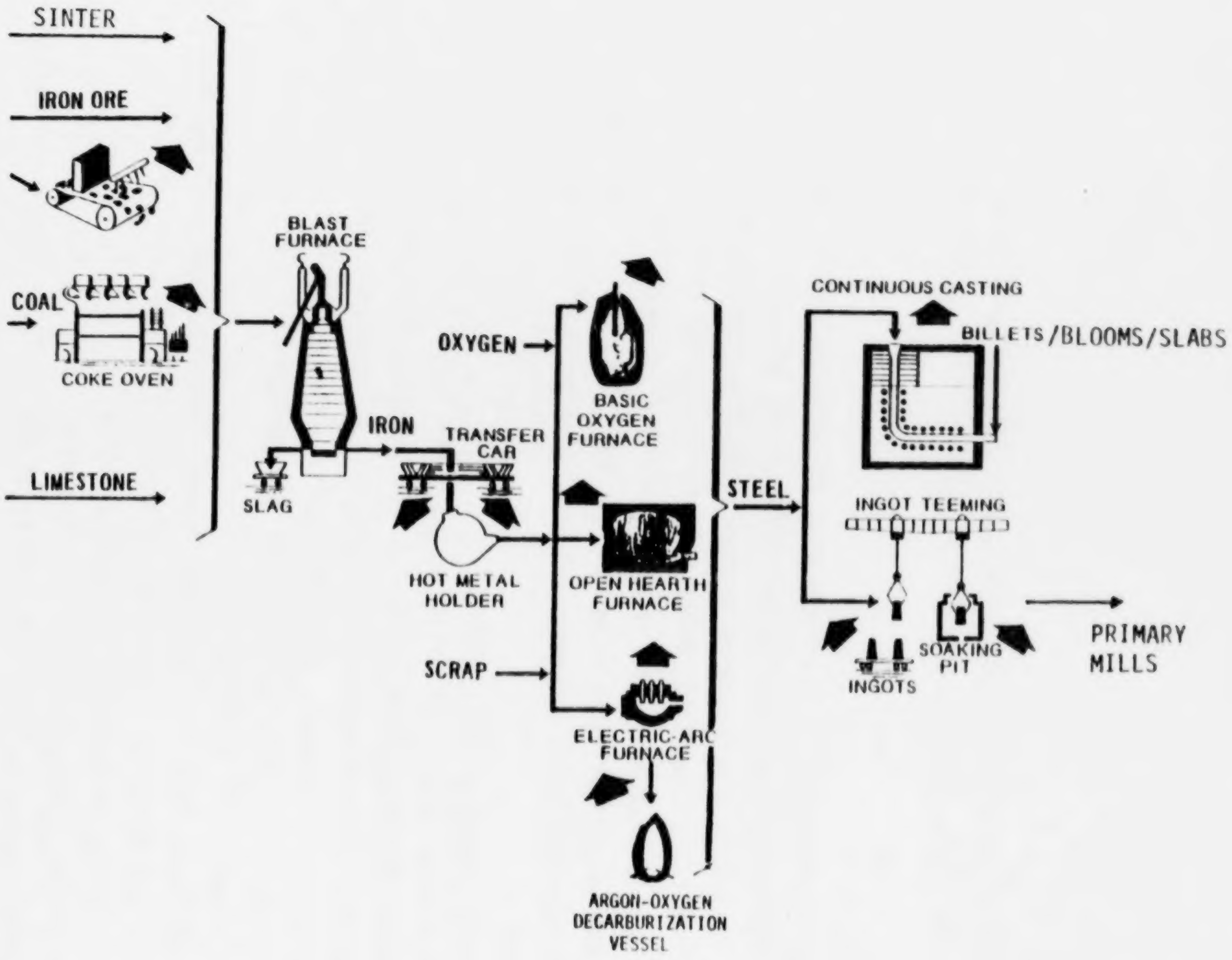
3.1 GENERAL

This chapter presents a description of the electric arc furnace (EAF) and argon-oxygen decarburization (AOD) vessel processes and their emissions. The source category is covered under the Standard Industrial Classification (SIC) Code 3312, Blast Furnaces and Steel Mills. Also discussed in this chapter is the selection of baseline emissions for EAF's and AOD vessels which will be used in later chapters to determine incremental environmental, economic, and energy impacts of the regulatory alternatives.

3.1.1 General Industry Description

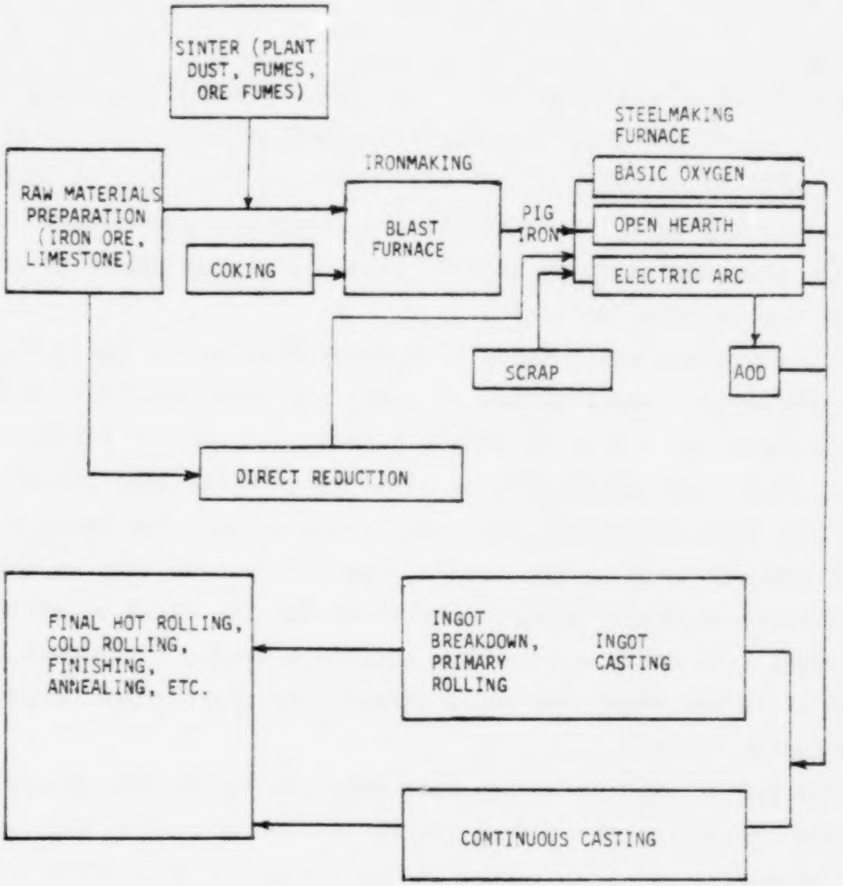
Major sources of air pollution in the steel industry are the basic oxygen process furnaces (BOPF's), EAF's, AOD vessels, open-hearth furnaces, blast furnaces, and coke plants (Figure 3-1). All processes emit large quantities of air pollutants, primarily particulate matter, if not properly controlled. This document will deal primarily with the EAF and AOD vessel segments of the industry.

The EAF's are typically utilized in semi-integrated and nonintegrated steel mills and specialty steel shops (Figure 3-2). The semi-integrated steel mills are a new class of integrated plants that utilize direct reduced iron (DRI) in addition to iron and steel scrap as a source of ferrous material (the manufacture and use of DRI will be briefly discussed later in the chapter). The nonintegrated steel mills operate melting units, such as an EAF, casting units, and fabrication mills and produce a limited range of products for a regional market. Mini-mills, a term that applies to nonintegrated steel mills that produce less than 544,200 Mg



SINTER
IRON ORE
COAL
COKE OVEN
LIMESTONE
BLAST FURNACE
SLAG
IRON
TRANSFER CAR
HOT METAL HOLDER
OXYGEN
SCRAP
BASIC OXYGEN FURNACE
OPEN HEARTH FURNACE
ELECTRIC-ARC FURNACE
ARGON-OXYGEN DECARBURIZATION VESSEL
STEEL
CONTINUOUS CASTING
BILLETS/BLOOMS/SLABS
INGOT TEEMING
INGOTS
SOAKING PIT
PRIMARY MILLS

Figure 3-1. Flow diagram of an iron and steel plant.[1]


SINTER (PLANT DUST, FUMES, ORE FUMES)
STEELMAKING FURNACE
IRONMAKING
RAW MATERIALS PREPARATION (IRON ORE, LIMESTONE)
BLAST FURNACE
PIG IRON
BASIC OXYGEN
OPEN HEARTH
ELECTRIC ARC
COKING
SCRAP
AOD
DIRECT REDUCTION
FINAL HOT ROLLING, COLD ROLLING, FINISHING, ANNEALING, ETC.
INGOT BREAKDOWN, PRIMARY ROLLING
INGOT CASTING
CONTINUOUS CASTING

POSSIBLE MAJOR ROUTES

INTEGRATED: COKING--BLAST FURNACE--BASIC OXYGEN--INGOT CASTING--FINISHING

NONINTEGRATED: SCRAP + DIRECT REDUCTION--ELECTRIC ARC + SECONDARY REFINING--CONTINUOUS CASTING--FINISHING

SEMI-INTEGRATED: DIRECT REDUCTION + SCRAP--ELECTRIC ARC + SECONDARY REFINING--CONTINUOUS CASTING--FINISHING

Figure 3-2. Schematic flowchart for integrated and nonintegrated steelmaking.[2]

(600,000 tons) of steel per year, typically use EAF's as metal melters.[2] Specialty steel companies produce stainless and alloy steels from steel making units and usually do not deal with raw iron ore. A specialty steel plant typically has electric arc furnaces, some secondary steel refining equipment such as an AOD vessel or vacuum degassing unit, and forming and rolling facilities.

There are two basic types of steel-producing EAF facilities: those that produce the common grades of steel (carbon steel) and those that produce stainless and alloy steels (specialty steel). Electric arc furnaces are used extensively as metal melters for both types of steel facilities with oxygen blowing used to assist in scrap metal meltdown. In the production of carbon steels, the EAF is also used as the refining vessel where oxygen blowing is performed for the final steel chemical adjustment. In addition, various additives needed to produce specific grades of carbon steel are added directly to the furnace or added to the ladle during a tap.

The EAF is used primarily as a metal melter in the specialty steel shop and the molten steel from the EAF is charged to an AOD vessel or other secondary refining vessel for refining. This practice allows shorter heat times and better quality control over the final product. Fewer additions are made and less oxygen blowing for molten steel chemistry adjustments is performed in the EAF when the AOD vessel is used for steel refining. This innovation in specialty steel production has gained widespread industry acceptance over the last 6 to 8 years.

Several factors tend to favor the trend toward the increased utilization of EAF's in steel production. They include the higher blast furnace energy costs, shorter starting periods for EAF's, large supplies of available steel scrap, the ability to utilize DRI, the growing use of specialty steels by industry, the growing number of mini-steel plants (which normally use EAF's exclusively), the adoption of ultrarapid steel melting technology, and the increased use of water-cooled panels and roofs to reduce refractory costs.[2-4]

The utilization of AOD vessels has increased in the last few years for several reasons. These reasons are: an interest in the reduction of EAF operating costs (less refining is required in the EAF when an AOD vessel is used), the ease of molten bath temperature adjustment, the simplicity of alloy refinement, the high quality of AOD-produced steel (similar in quality to vacuum-degassed steel), the improved operating control (over that of an EAF) in refining molten steel, the significant savings in the use of alloys, and the increase in the melt capacity of the shop when the EAF is used only as a melting device.[2,5,6]

In 1980, EAF's in the United States produced 28.2 $\times 10^6$ megagrams (Mg) (31.2 $\times 10^6$ tons) of steel.[7] Of this total, 71.6 percent was carbon steel, 23.0 percent was alloy steel, and 5.4 percent was stainless steel. This accounts for 23.6 percent of the carbon steel, 46.3 percent of the alloy steel, and 100 percent of the stainless steel produced from all furnace types in the United States.[7] In 1980, 96 percent of the steel produced by EAF's was made from recycled iron and steel scrap, and the remainder of the steel was produced with blast furnace hot metal and DRI.[7,8] EAF's and AOD vessels are well suited for producing alloy steels where only small batches are needed. In 1980, AOD vessels in the United States refined approximately 2,131,900 Mg (2,350,000 tons) of specialty steels, with much of this tonnage being stainless steel.

In 1981, there were 327 EAF's in the United States that were operated by 87 companies in 130 locations (Table 3-1). These plants are in 36 States, with 63 percent of the plants located in 8 States (Table 3-2). Of the 327 EAF's approximately 10 percent or 32 furnaces are subject to the existing new source performance standard. The EAF capacities range from 4.5 Mg (5 tons) to 363.9 Mg (400 tons).[9-11] The percentages of EAF's within a range of capacities are listed in Table 3-3. Many of the smaller furnaces are in shops that produce small quantities of specialty steels.

There were 27 AOD vessels in operation in the United States in 1981. These vessels were operated by 19 companies with 23 locations in 9 States (Table 3-4). AOD vessel capacities range from 3.6 Mg (4 tons) to 158.8 Mg (175 tons).[13] The percentages of AOD vessels within a range of capacities are listed in Table 3-3 along with the EAF size ranges.

3.1.2 Industry Growth and Projections

The demand for steel has increased from nonresidential and nonautomotive segments of industry, such as nonresidential construction and the production of durable goods (notably machinery, industrial equipment,

TABLE 3-1. ELECTRIC ARC FURNACES IN STEEL MILLS IN THE UNITED STATES--1981[9-12]

Plant/location	No. of furnaces	Operating capacity (Mg)
AL TECH SPECIALTY STEEL CORP.		
Watervliet, N.Y.	2	29.0
ALLEGHENY LUDLUM STEEL CORP.		
Brackenridge, Pa.	1	49.9
	2	63.5
	2	72.6
ARMCO, INC.		
· Baltimore Works	1	45.4
Baltimore, Md.	1	36.3
· Butler Works	3	149.7
Butler, Pa.		
· Houston Works	2	106.1
Houston, Tex.	4	158.8
· Kansas City Works	2	113.4
Kansas City, Mo.	4	136.1
· National Supply Division	1	9.1
Torrance, Calif.	1	20.0
ATLANTIC STEEL CO.		
· Atlanta Works	2	77.1
Atlanta, Ga.		
· Cartersville Works	1	90.7
Cartersville, Ga.		
AUBURN STEEL CO.		
Auburn, N.Y.	1	54.4
BABCOCK & WILCOX CO.		
Beaver Falls, Pa.	2	22.7
	2	45.4
	2	68.0
	3	90.7
BAYOU STEEL CORP.		
New Orleans, La.	2^a	54.4
BETHLEHEM STEEL CORP.		
· Bethlehem Plant	1	27.2
Bethlehem, Pa.	2	49.9
	2	54.4
· Steelton Plant	3	154.2
Steelton, Pa.		
· Johnstown Plant	2^a	163.3
Johnstown, Pa.		
BETHLEHEM STEEL CORP. (cont.)		
· Los Angeles Plant	2	90.7
Los Angeles, Calif.		
· Seattle Plant	2	103.8
Seattle, Wash.		
BORDER STEEL MILLS, INC.		
El Paso, Tex.	2	22.7
BW STEEL, INC.		
Chicago Heights, Ill.	2	27.2
CABOT CORPORATION		
Stellite Div.	1	4.5
Kokomo, Ind.	1	13.6
CAMERON IRON WORKS, INC.		
Houston, Tex.	2	54.4
CARPENTER TECHNOLOGY CORP.		
· Steel Division	2	38.1
Bridgeport, Conn.		
· Reading Plant	5	13.6
Reading, Pa.	$1^{a,b}$	27.2
CASCADE ROLLING MILLS		
McMinnville, Oreg.	2	22.7
CCS BRAEBURN ALLOY STEEL DIV.		
Lower Burrell, Pa.	2	9.1
THE CECO CORP.		
· Lemont Manufacturing Co.	3	36.3
Lemont, Ill.		
· Milton Manufacturing Co.	3	18.1
Milton, Pa.		
CF&I STEEL CORP.		
Pueblo, Colo.	2	108.8
CHAPARRAL STEEL CO.		
Midlothian, Tex.	1	104.3
	$1^{a,b}$	136.0
CHARTER ELECTRIC MELTING CO.		
Chicago, Ill.	1	38.1
COLT INDUSTRIES		
· Crucible Stainless Steel	1	40.8
Div., Midland, Pa.	4	90.7
	2^a	154.2
· Crucible Specialty Metals	1	13.7
Div., Syracuse, N.Y.	1	18.2
	1	31.9
COLUMBIA TOOL STEEL CO.		
Chicago Heights, Ill.	1	4.5
	1	7.3
CONNORS STEEL CO.		
· Birmingham Works	2	40.8
Birmingham, Ala.		
· Huntington Works	2	45.4
Huntington W. Va.		
COPPERWELD STEEL CO.		
Warren, Ohio	5	81.6
CYCLOPS CORP.		
· Empire Detroit Steel Div.	2	90.7
Mansfield, Ohio		
· Universal Cyclops	2	18.1
Specialty Steel	1	36.3
Bridgeville, Pa.		
EASTERN STAINLESS STEEL CO.		
Baltimore, Md.	1	45.4
	1^a	54.4
EDGEWATER STEEL CORP.		
Oakmont, Pa.	1	45.4
ELECTRALLOY CORP.		
Oil City, Pa.	1	31.8
FINKLE & SONS CO.		
Chicago, Ill.	2	59.0
FLORIDA STEEL CORP.		
· Charlotte Mill	1	22.7
Charlotte, N.C.	1^a	36.3
· Indiantown Mill	1	27.2
Indiantown, Fla.	1	31.8

(continued)

TABLE 3-1. (continued)

Plant/location	No. of fur- naces	Operating capacity (Mg)
FLORIDA STEEL CORP. (cont.)		
· Baldwin Mill Baldwin, Fla.	1[a]	68.0
· Tampa Mill Tampa, Fla.	1 1 1	18.1 27.2 31.8
· Jackson Mill Jackson, Tenn.	1[a]	120.0
GREEN RIVER STEEL Owensboro, Ky.	2	54.4
GUTERL SPECIAL STEEL CORP. Lockport, N.Y.	3	13.6
HAWAIIAN WESTERN STEEL LTD. Ewa, Hawaii	1	31.8
HUNT STEEL CO. Youngstown, Ohio	1	54.4
HURRICANE INDUSTRIES INC. Sealy, Tex.	1	36.3
ILLINOIS BIRMINGHAM BOLT Kankakee, Ill.	2	20.9
INGERSOL JOHNSON STEEL CO. New Castle, Ind.	2 2	8.2 10.9
INGERSOL RAND-OIL FIELD PROD. Pampa, Texas	1	36.3
INLAND STEEL CO. East Chicago, Ind.	2	108.8
INTERCOASTAL STEEL CORP. Chesapeake, Va.	2	18.1
INTERLAKE, INC.		
Hoeganaes Corporation Gallatin, Tenn.	1[a]	49.9
ITT HARPER Morton Grove, Ill.	1 1	4.5 9.1
JARSCO Roebling, N.J.	1	40.8
JESSOP STEEL CO.		
· Washington Works Washington, Pa.	3	18.1
JONES & LAUGHLIN STEEL CORP.		
· Cleveland Works Cleveland, Ohio	2	167.8
· Pittsburgh Works Pittsburgh, Pa.	2[a]	317.5
· Warren Works Warren, Mich.	5	72.6
EARLE M. JORGENSEN CO. Seattle, Wash.	2	36.3
JOSLYN STAINLESS STEELS Fort Wayne, Ind.	2 1	15.4 18.1
JUDSON STEEL CORP. Emeryville, Calif.	1	40.8
KENTUCKY ELECTRIC STEEL CO. Ashland, Ky.	2[a]	45.4
KEYSTONE CONSOLIDATED INDUSTRIES, INC.		
Keystone Group Steel Works Peoria, Ill.	2	154.2
KNOXVILLE IRON CO. Knoxville, Tenn.	2	31.7
KORF INDUSTRIES		
· Georgetown Steel Corp. Gerogetown, S.C.	3	68.0
· Georgetown Texas Steel Corp., Beaumont, Tex.	2	99.8
LACLEDE STEEL CO. Alton, Ill.	2	204.1
LATROBE STEEL CO. Latrobe, Pa.	1 2	4.5 27.2
LONESTAR STEEL CO. Lone Star, Tex.	2[a]	54.4
LUKENS STEEL Coatsville, Pa.	2 2	136.1 163.3
MARATHON LE TOURNEAU CO. Longview, Tex.	2	22.7
MARATHON STEEL CO. Tempe, Ariz.	3	22.7
MARION STEEL CO. Marion, Ohio	2	27.2
McCLOUTH STEEL CORP. Trenton, Mich.	2	181.4
MISSISSIPPI STEEL DIV. Flowood Works Flowood, Miss.	2 1	12.7 31.7
NATIONAL FORGE CO.		
· Erie Plant Erie, Pa.	1 2	31.7 68.0
· Irvine Forge Division Irvine, Pa.	1 1	18.1 40.8
NATIONAL STEEL CORP. Great Lakes Steel Div. Ecorse, Mich.	2	136.4
NEW JERSEY STEEL & STRUCTURE CORP. Sayerville, N.J.	2	59.0
NEWPORT STEEL Newport, Ky.	3	77.1
NORTH STAR STEEL CO.		
· St. Paul Plant St. Paul, Minn.	2	54.4
· Monroe Plant Monroe, Mich.	1[a]	108.8
· Wilton Plant Wilton, Iowa	1	54.4

(continued)

TABLE 3-1. (continued)

Plant/location	Number of fur-naces	Operating capacity (Mg)
NORTHWEST STEEL ROLLING MILLS, INC. Kent, Wash.	2	31.7
NORTHWESTERN STEEL & WIRE CO. Sterling, Ill.	3	362.9
NUCOR CORP.		
· Darlington Mill Darlington, S.C.	3	31.7
	2[a]	31.7
· Jewett Mill Jewett, Tex.	2	36.3
	3[a]	45.4
· Norfolk Mill Norfolk, Nebr.	2	36.3
	2[a]	36.3
	1[a,b]	36.3
· Plymouth Mill Plymouth, Utah	2[a]	54.4
OREGON STEEL MILLS Portland, Oreg.	2	68.0
OWENS ELECTRIC STEEL COMPANY Cayce, S.C.	1	9.1
	1	22.7
	1	31.7
PENN-DIXIE STEEL CORP. Kokomo Plant Kokomo, Ind.	2	158.8
PHOENIX STEEL CORP. · Plate Div. Claymont, Del.	2	136.1
QUANTEX CORP. · Mac Steel Michigan Div. Jackson, Mich.	2	36.3
· Mac Steel Arkansas Div. Fort Smith, Ark.	2	54.4
RARITAN RIVER STEEL CO. Perth Amboy, N.J.	1[a]	117.9
RAZORBACK STEEL CORP. Newport, Ark.	2	22.7
REPUBLIC STEEL CORP. · Central Alloy Works Canton, Ohio	3	77.1
	4	181.4
· South Chicago Works South Chicago, Ill.	3	181.4
ROANOKE ELECTRIC STEEL CORP. Roanoke, Va.	2	20.0
	1	36.3
	1[a,b]	77.1
ROBLIN STEEL CO. Dunkirk Works Dunkirk, N.Y.	2	27.2
	1[a]	27.2
ROSS STEEL WORKS Amite, La.	2	9.7
	1	36.3
ROUGE STEEL CO. Dearborn, Mich.	2	181.4
SHARON STEEL CORP. Sharon, Pa.	2[a]	117.9
SHEFFIELD STEEL CORP. Sand Springs, Okla.	2	68.0
SOULE STEEL CO. Carson Works Carson, Calif.	2	20.0
SOUTHERN UNITED STEEL CORP. Birmingham, Ala.	2	13.6
STANDARD STEEL ENTERPRISE Freedom Forge Corp. Burnham, Pa.	1	16.3
	1	36.3
	1	40.8
	1	63.5
Latrobe, Pa.	1	27.2
STRUCTURAL METALS, INC. Sequin, Tex.	1	45.4
	1[a]	81.6
TAMCO Etiwanda, Calif.	1	95.3
TELEDYNE VASCO Latrobe, Pa.	1	13.6
TENNESSEE FORGING STEEL CORP. · Harriman Works Harriman, Tenn.	3	22.7
TEXAS STEEL CO. Fort Worth, Tex.	1	7.3
	1	10.9
	1	22.7
	1	27.2
TIMKEN CO. · Steel and Tube Div. Canton, Ohio	1	54.4
	4	90.7
	3	136.1
UNION ELECTRIC STEEL CORP. Burgettstown, Pa.	1	31.8
UNITED STATES STEEL CORP. · Fairless Work Fairless Hills, Pa.	2	181.4
· Johnstown-Center Works Johnstown, Pa	2	4.5
	1	27.2
· National Duquesne Works Duquesne, Pa.	1	18.1
	1	63.5
	3	77.1
· South Works South Chicago, Ill.	1	90.7
	2	181.4
· Texas Works Baytown, Tex.	2	181.4
	2	204.1
WASHINGTON STEEL CO. Fitch Works Houston, Pa.	2	40.8
WITTEMAN STEEL MILLS Fontana, Calif.	1	22.7

[a] Subject to existing NSPS.

[b] Completion date Spring 1982.

TABLE 3-2. LOCATION OF STEEL PLANTS WITH EAF'S AND AOD VESSELS--1981[10-13]

State	Plants	
	EAF	AOD vessel
Alabama	3	
Arizona	1	
Arkansas	2	
California	6	
Colorado	1	
Connecticut	1	1
Delaware	1	
Florida	3	
Georgia	2	
Hawaii	1	
Illinois	12	1
Indiana	5	3
Iowa	1	
Kentucky	3	
Louisiana	2	
Maryland	2	2
Michigan	6	1[a]
Minnesota	1	
Mississippi	1	
Missouri	1	
Nebraska	1	
North Carolina	1	
New Jersey	3	
New York	5	2
Ohio	7	2
Oklahoma	1	
Oregon	2	
Pennsylvania	28	10
Rhode Island	1	
South Carolina	3	
Tennessee	4	
Texas	13	
Utah	1	
Virginia	2	
Washington	3	1
West Virginia	1	
	130	23

[a] Another plant in Michigan has not operated its AOD vessel since it was installed in 1977.

TABLE 3-3. INDUSTRY PERCENTAGES OF EAF'S AND AOD VESSELS BY CAPACITY--1981[10-13]

EAF's		AOD vessels	
Capacity range (Mg)	Percentage	Capacity range (Mg)	Percentage
Under 50	51	Under 25	41
50-99.9	26	25-49.9	33
100-149.9	10	50-99.9	22
150-199.9	11	Greater than 100	4
200-299.9	1		
Greater than 300	1		

TABLE 3-4. ARGON-OXYGEN CARBURIZATION VESSELS IN THE UNITED STATES--1981[13]

Plant and location	No. of vessels	Vessel capacity (Mg)
AL TECH SPECIALTY STEEL CORP. Watervliet, N.Y.	2	29.0
ALLEGHENY LUDLUM STEEL CORP. Brackenridge, Pa.	1	90.7
ARMCO, INC.		
· Baltimore Works Baltimore, Md.	1	36.3
· Butler Works Butler, Pa.	1	158.8
BABCOCK AND WILCOX CO. Beaver Falls, Pa.	1	22.7
CABOT CORP. Stellite Div. Kokomo, Ind.	1 1	3.6 13.6
CARPENTER TECHNOLOGY CORP.		
· Steel Div. Bridgeport, Conn.	1	45.4
· Reading Plant Reading, Pa.	1 1	13.6 18.1
CRUCIBLE, INC.		
· Stainless Steel Div. Midland, Pa.	1	90.7
· Specialty Metals Div. Syracuse, N.Y.	1	36.3
CYCLOPS CORP.		
· Universal Cyclops Specialty Steel Bridgeville, Pa.	1	45.4[a]
· Empire-Detroit Div. Mansfield, Ohio	1	90.7
EASTERN STAINLESS STEEL CO. Baltimore, Md.	1	45.4
ELECTRALLOY CORP. Oil City, Pa.	1 1	15.4 27.2
INGERSOL JOHNSON STEEL COL. New Castle, Ind.	1	13.6
JESSOP STEEL CO. Washington Works Washington, Pa.	1	18.1
JONES AND LAUGHLIN STEEL CORP. Warren Works Warren, Mich.	1	72.6
EARL M. JORGENSEN STEEL CO. Seattle, Wash.	1	31.8
JOSYLN STAINLESS STEELS Fort Wayne, Ind.	1	17.2
McLOUTH STEEL CORP. Trenton, Mich.	(1)[b]	90.7
REPUBLIC STEEL CORP. Central Alloy Works Canton, Ohio	1	90.7
STANDARD STEEL DIV. Burnham, Pa.	1 (used) 1 (idle)	13.6 18.1
U.S. STEEL CORP. South Works Chicago, Ill.	1	90.7
WASHINGTON STEEL CO. Fitch Works Houston, Pa.	1	36.3

[a] Facility has second vessel (22.7 Mg) that can be used in the single trunion ring.

[b] Has not operated since installation in 1977.

and railroad equipment).[14] The decline in residential construction has been accompanied by a decline in steel orders from the appliance industry. Shipments to the automotive industry declined in 1980 because of the demand for smaller, lighter cars, which require less steel to produce.[2] In addition, the use in the automotive industry of lighter-than-steel substitutes, such as plastics and aluminum, has resulted in a further decline in demand of steel for cars.[2]

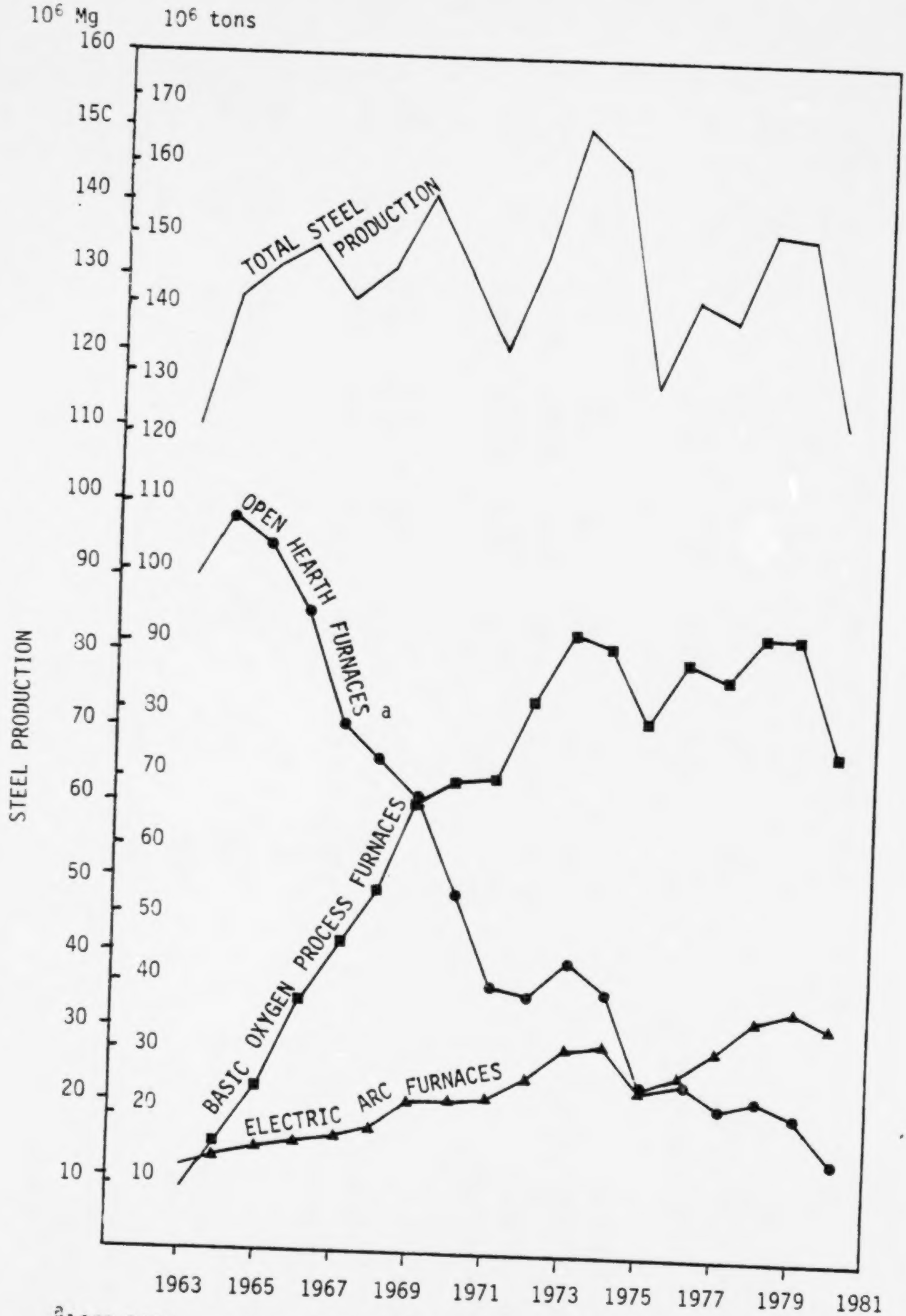
A summary of the steel industry production, apparent domestic consumption, shipment weight and value, export-import weights and values, and employment for the period 1976 to 1988 is presented in Table 3-5.[12,14] Industry predictions for 1981 call for 94.3 $\times 10^6$ Mg (104 $\times 10^6$ tons) in apparent domestic consumption.[15] Weaknesses in the automotive, service center, and agricultural markets in 1980 will be partially offset by an increased demand for oil- and gas-drilling equipment and rail transportation equipment, as well as a steady market for cans and closures.[14,15] The projected apparent domestic consumption of steel for 1985 is 108 $\times 10^6$ Mg (119 $\times 10^6$ tons).[14] In order to meet the demand that industry projects for 1990, a 12 percent increase in total steel production capacity (19.1 $\times 10^6$ Mg [21 $\times 10^6$ tons]) will be needed to provide for 85 percent of the U.S. consumption.[15] This figure assumes that imported steel will capture 15 percent of the market.[15] This production capacity increase would mean a 2 percent annual growth rate between 1980 and 1990 for all furnace types.

Growth in the use of electric arc furnaces in steelmaking has been steady for the past 18 years except for the recession period of 1974 to 1975 and the depressed economy in 1980-1981. Figure 3-3 shows the trends for the past 18 years for the total production of steel and for the production of steel from the three major types of furnaces: open hearth, basic oxygen process, and electric arc. The total raw steel production in 1980 was 101.5 $\times 10^6$ Mg (111.8 $\times 10^6$ tons).[7] The basic oxygen process furnace accounted for 60.4 percent of the total steel produced (up from 8 percent in 1963) while electric arc furnace production accounted for 27.9 percent (up from 10 percent in 1963). These gains were at the expense of open hearth furnace production, which accounted for 11.7 percent in 1980 (down from 82 percent in 1963).[7]

TABLE 3-5. STEEL INDUSTRY DATA AND PROJECTIONS[14],[15]

Steel industry data	1976	1977	1978	1979	1980	1981	1985[a]	1988[b]
Raw steel production, 10^6 Mg (10^6 tons)	116 (128)	113 (125)	124 (137)	123 (136)	101 (111)	114 (126)	N/A[c] N/A	143 (158)
Apparent domestic consumption, 10^6 Mg (10^6 tons)	91.7 (101.1)	98.7 (108.8)	105.8 (116.6)	104.3 (115.0)	82.5 (90.9)	94 (104)	108 (119)	N/A N/A
Steel mill products								
Industry shipments, 10^6 Mg (10^6 tons)	81 (89)	83 (91)	89 (98)	91 (100)	74 (82)	83 (91)	94 (104)	106 (117)
Value, 10^6 dollars	32,762	36,302	42,828	48,373	40,381	49,358	N/A	N/A
Average value, \$/Mg (\$/ton)	404.47 (368.11)	437.37 (398.92)	481.21 (437.02)	531.6 (483.7)	545.7 (492.4)	594.7 (542.4)	N/A N/A	N/A N/A
Exports								
Quantity, 10^6 Mg (10^6 tons)	2.4 (2.7)	1.8 (2.0)	2.2 (2.4)	2.5 (2.8)	3.7 (4.1)	2.3 (2.5)	2.3 (2.5)	N/A N/A
Value, 10^6 dollars	1,255	1,037	1,329	1,878	2,604	1,832	N/A	N/A
Imports								
Quantity, 10^6 Mg (10^6 tons)	13 (14)	17 (19)	19 (21)	16 (18)	14 (15)	14.1 (15.5)	N/A N/A	N/A N/A
Value, 10^6 dollars	4,025	5,531	6,917	6,967	6,585	7,444	N/A	N/A
Total employment, 10^3 persons	469	470	472	477	429	472	N/A	N/A

[a] Projections.[12]
[b] Projections.[14]
[c] N/A = not available.



[a] 1963-1968 open hearth data included Bessemer furnace production.

Figure 3-3. Steel production by furnace type.[7]

The use of electric arc furnaces is expected to continue to increase. The growth in EAF capacity in 1981 was very large. During 1981, 4.4 $\times 10^6$ Mg (4.9 $\times 10^6$ tons) of capacity came on line.[12] Estimates of future EAF growth vary. One source indicates that EAF's will produce 40.8 $\times 10^6$ to 42.6 $\times 10^6$ Mg (45 $\times 10^6$ to 47 $\times 10^6$ tons) of steel per year, or 30 percent of the steel made in this country, by 1985.[16] Another forecast calls for an annual growth rate of 5 percent, reaching a level of 44.4 $\times 10^6$ Mg (50 $\times 10^6$ tons) per year by 1990.[17,18] The most optimistic prediction calls for an even more prolific future with EAF's producing half the nation's raw steel by 1990.[16]

For this document, the projected EAF production share of the total domestic raw steel production in 1987 (119.7 $\times 10^6$ Mg [132 $\times 10^6$ tons]) will be 31.5 percent. It is projected that the total EAF capacity in 1987 will be 44.4 $\times 10^6$ Mg (48.9 $\times 10^6$ tons) and that with an 85 percent utilization rate EAF's will produce 37.7 $\times 10^6$ Mg (41.6 $\times 10^6$ tons) of raw steel in 1987.[15] These estimates are conservative compared to other growth projections and may prove to be low when the economy improves as the recession ends. In addition, if import restriction are placed into effect, the domestic raw steel production should improve.

Growth in the use of AOD vessels is expected to be small in the stainless steel industry since most of the existing steel mills that produce stainless steel already have AOD vessels. Any new AOD vessels will be part of a new steel plant rather than retrofits into an existing shop. The vendor that supplies AOD vessels estimates that one or two vessels per year will be installed in the specialty steel industry.[19] This number would be higher if the use of AOD vessels was increased in the shops that produce alloy steels and no stainless steels.[20]

3.2 PROCESS FACILITIES AND THEIR EMISSIONS

3.2.1 Electric Arc Furnace Components

The electric arc furnace process for steelmaking was developed in Europe during the 1800's. The first successful commercial installation was placed in operation in France in 1899 by Paul Heroult. The first EAF installation in the United States was at the Halcomb Steel Company, Syracuse, New York, in 1906.[21]

The direct electric arc furnace used today is a refractory-lined, cylindrical vessel made of heavy, welded steel plates and having a bowl-shaped hearth and a dome-shaped roof (Figure 3-4). Many of the new furnaces use water-cooled wall panels to reduce refractory costs and cool the surrounding working environment. Three graphite or carbon electrodes are mounted on a superstructure above the furnace and can be lowered and raised through holes in the furnace roof. The electrodes convey the energy for melting the scrap charge. Water-cooled glands are provided at the holes to cool the electrodes and minimize the gap between the electrodes and roof openings to reduce fugitive emissions, noise levels, electrode oxidation, and heat losses. The furnace is usually mounted on curved rocker trunnions. Hydraulic cylinders or electromechanical means are used for tilting the furnace.

The main items of electrical equipment are a circuit breaker, a step-down transformer, and, for small transformers, a tapped reactor to give arc stability and to dampen current surges. The transformers that regulate the electricity to an EAF are designed for connection to a high voltage supply. The transformer is provided with equipment to give a range of secondary voltages ("taps") to suit the melting, superheating, and refining conditions in the furnace. The transformer taps are changed in preprogrammed steps to provide the necessary voltage for the melting and refining of the scrap.

The electrodes are raised or lowered by electromechanical or electrohydraulic devices. At a given transformer voltage, lowering the electrodes shortens the arc and increases the current and power input and raising the electrodes has the reverse effect. Electrode movement is accomplished by automatic control in normal operation.

A recent development in the use of EAF's has been the ultra-high power (UHP) furnace. These furnaces utilize much larger transformers than traditional EAF's. A traditional 100-ton EAF might use 20-megavolt-ampere (MVA) transformers whereas a 100-ton UHP furnace would use 40- to 50-MVA transformers.[16] The typical figure used for determining the transformer size for a UHP furnace is 0.55 MVA per Mg (0.5 MVA per ton) of heat size, compared to approximately 0.22 MVA per Mg (0.2 MVA per ton) of heat size for a conventional EAF.[16] The new UHP furnaces use larger electrodes

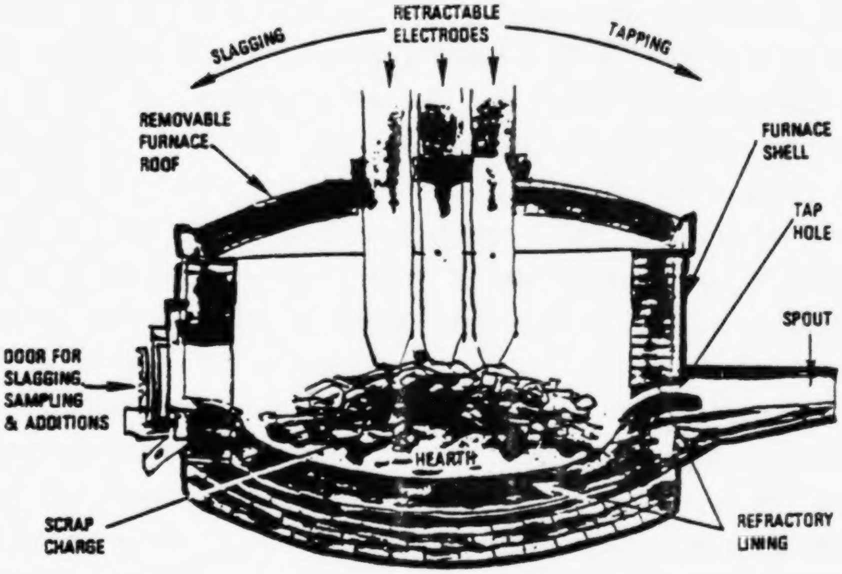

RETRACTABLE ELECTRODES
SLAGGING
TAPPING
REMOVABLE FURNACE ROOF
FURNACE SHELL
TAP HOLE
SPOUT
DOOR FOR SLAGGING, SAMPLING & ADDITIONS
HEARTH
SCRAP CHARGE
REFRACTORY LINING

Figure 3-4. Electric arc steel furnace.

than those used by normal powered EAF's that allows more power input to the charge (and thus a faster melting rate) and increases the production rate (a 100-ton normal power EAF has a heat time of about 3 hours while a 100-ton UHP EAF has a heat time of about 1 to 2 hours). Oxyfuel burners and oxygen lances may also be used to increase the melt rate in UHP furnaces.[16]

The faster melting had a detrimental effect on refractory linings until the use of water-cooled side wall panels and roofs was revived. The use of water-cooled side panels and roofs allows for faster melting without the associated detrimental effects on the furnace refractory and lining. One company utilizes two 317.5-Mg (350-ton) UHP furnaces that are melting at a rate of 95.3 Mg/h (105 tons/h) each.[16] This speed of melting approaches the speed of other melting processes, which increases the competitiveness of the EAF in the steel market.

The furnace refractories used in producing steel are mainly basic. Acidic refractories in EAF's are typically used only in steel foundries and forging shops. The bottoms of basic-lined arc furnaces used in the steel industry consist of a burned magnesite brick subhearth with a working surface approximately 30.5 centimeters (cm) (12 inches [in.]) thick of magnesia rammed material. Basic arc furnace roofs are generally constructed of high-alumina brick with high-alumina rammed or castable materials for the center section around the electrodes.[21,22]

With the electrodes raised, the furnace roof can be swung aside to permit the charge materials to be dropped into the furnace (top charged). Additional alloying agents, as required, are added through the slag door of the furnace or through a separate hole in the furnace roof. Top charging of materials is the most economical method because a furnace can be completely charged within a few minutes.

Openings are provided on both sides of the furnaces (the tap hole, and the slag door). The temperature of the molten bath is checked and samples for laboratory analysis are taken through the slag door. For furnace operations that require oxygen blowing, the oxygen lance can be inserted through the partially open slag door or through a separate opening in the side of the EAF. Oxygen lances supply oxygen that is used as a fuel gas to increase the rate of scrap melting and speed up the oxidizing of carbon and silicon and the impurities in the molten steel.[16,21]

3.2.1.1 EAF Operation. The production of steel in an EAF is a batch process where "heats" or cycles range from 1 to 5 hours, depending upon the size and quality of the charge, the power input to the furnace, and the desired quality of the steel produced. Each heat consists of charging and backcharging, meltdown and refining, and tapping. Cold steel scrap and sometimes DRI are charged to begin a cycle, and alloy materials and fluxing agents are added for refining. Direct reduced iron is produced from iron ores that are reduced in the presence of excessive quantities of a reducing agent (natural gas, noncoking bituminous coal, anthracite, lignite, etc.) to produce low carbon iron which is used as melting stock along with scrap iron and steel.[2] The DRI is used as a scrap supplement and as a diluent for residuals in the scrap. Many of the new electric shops are designed to allow for continuous DRI charging through a slot in the roof or side wall. The use of DRI is currently limited in the United States because of the high cost and the availability of the primary reducing agent, natural gas, and because of the relatively low cost and adequate supply of scrap. Currently there are several demonstration plants in the United States that produce DRI with coal as the reducing agent.[23] The coal-based reduction process may provide a more economical means of producing DRI.

There are circumstances that may delay the operation of an electric arc furnace. "Sheds" (the cutting off of the power to the electrodes) occur frequently and might not be considered unusual operating delays. Other delays that might be considered typical, are:

1. Lack of room on the ingot floor (teeming aisle delay);
2. Malfunction of an AOD vessel or continuous casting unit;
3. Delay or malfunction of the crane;
4. Failure of the electrode lifting mechanism;
5. Improper arcing of electrodes;
6. Loss of plant power; and
7. An inoperative furnace roof which cannot be opened or closed.[24]

3.2.1.1.1 Charging. Iron and steel scrap are loaded into a drop-bottom (clam-shell type) charge bucket with an electromagnet that is suspended from an overhead crane. The charge bucket is filled to a specified weight and weighed on a scale that has a digital display that is observed by the crane operator. When the roof of the furnace has been opened, charging is normally performed by carefully dropping the charge into the open arc furnace from the charge bucket. Some smaller furnaces are charged with scrap directly from the suspended electromagnet and do not utilize a charge bucket.

All steel plants except one charge cold scrap to the electric furnaces. One melt shop routinely charges blast furnace metal to the EAF's, and the molten metal is 36 to 40 percent of the total charged material. Molten steel can be refurnaced (i.e., the molten steel is tapped into a ladle and then the steel is poured back into the furnace). Refurnacing may be done to salvage an off-grade or cold heat batch or to keep the steel hot due to a production delay or breakdown elsewhere.[21]

A large variety of scrap is charged to EAF's. According to the Institute of Scrap Iron and Steel, all grades of scrap are to be almost free of dirt, nonferrous metals, and foreign material of any kind. Carbon steel shops typically use No. 1 and No. 2 grades of scrap, while specialty shops typically use No. 1 scrap, stainless scrap, and alloys such as ferromanganese, ferrochrome, high carbon chrome, nickel, molybdenum oxide, aluminum, manganese-silicon, and others.

Scrap size and bulk density vary from light scrap, such as machine turnings, to heavy scrap, such as ingot butts. The charge bucket is usually loaded with light scrap at the bottom for two reasons: to provide a cushioning for the impact of the charge on the bottom of the EAF and because the light scrap melts quicker than denser scrap which aids in forming a molten metal pool in the bottom of the furnace.[22] Alloying materials that are not easily oxidized (such as copper, nickel, and molybdenum) and lime are charged before, or along with, the scrap metal charge. The lime is a fluxing agent to reduce the sulfur and phosphorus content in the molten steel. Depending on the desired carbon content of the steel and the finished product specifications, iron ore and coke may be charged prior to meltdown.

Charging the open furnace produces emissions that are difficult to control. The intensity level of emissions during charging varies depending on the cleanliness and the makeup of the scrap. Most charging emissions result from (1) vaporization of oil, grease, or dirt introduced with any turnings, borings, or chips; (2) oxidation of organic matter that may adhere to the scrap; and (3) the vaporization of water from wet or icy scrap.[22,24] Charging emissions are made up of particulate matter, carbon monoxide, hydrocarbon vapors, and soot.[24] The carbon monoxide is quickly oxidized to carbon dioxide in ambient air. Backcharging produces a large eruption of reddish-brown fumes with a strong upward thermal driving force. The emissions during backcharging are higher than during the initial charge because of the intense reaction that occurs due to the heat of the molten steel bath in the furnace.

During the charging process, the scrap must be introduced into the furnace so that there is no damage to the refractory. If scrap pieces remain above the furnace ring, the pieces must be repositioned so that the roof can swing back into place for meltdown. This repositioning can be done by hand or by compressing the scrap with the charge bucket or other large mass of metal suspended from the crane. An oxygen lance is sometimes used to cut any pieces blocking the roof. After the roof is rotated into place, it is lowered onto the furnace in preparation for meltdown. Repositioning of the scrap delays the closing of the roof, allowing more emissions to escape from the furnace.

3.2.1.1.2 Meltdown and refining. After the roof is in place, the electrodes are mechanically lowered to within 2.5 cm (1 in.) of the scrap, and the power is turned on.[21] When the current is applied to the electrodes, the electrodes are slowly lowered by automatic controls until they touch the scrap. During the first 3 to 5 minutes, an intermediate voltage is applied to the charge to allow the electrodes to bore into the scrap, which, in effect, shields the sides and roof of the furnace from the heat of the arc.[21] Melting is accomplished by the heat supplied by direct radiation from the arcs formed between the electrodes of the furnace and the metallic charge, by direct radiation from the furnace lining, and by the resistance of the metal between the arc paths. The arcs melt scrap directly beneath and around the electrodes, "boring" through the scrap charge and forming a pool of molten metal on the furnace hearth.[21,25] The molten steel pool, in turn, enhances meltdown by the radiation of heat from below into the cold scrap. After the initial period, the maximum voltage is applied in order to melt the charge as fast as possible. Before the scrap is entirely melted, a bank of refractory material (such as dolomite) is built in front of the slagging door to prevent the molten steel from spilling out the door.

When the initial scrap charge is almost entirely molten, a backcharge of scrap may be added to the furnace (in some shops there may be more than one backcharge). Following the backcharge, the roof is replaced, and electrodes are lowered and energized to melt the scrap. Near the end of the meltdown, oxygen lancing may be performed.

Oxygen lancing in arc furnaces is used mainly for adjusting of the chemistry of the steel, for speeding up the melting process, and for superheating the bath. Oxygen lancing results in increased bath and gas temperatures, gas evolution, and generation of particulates. Oxygen is now used almost universally (instead of iron ore or mill scale) for "boiling" a heat of steel to flush out gases, mainly hydrogen and nitrogen. Oxygen may increase the steel temperature without the arcs because the carbon boil reaction is exothermic. Oxygen lancing can be carried out with moderate rates of oxygen addition, thereby avoiding excessive generation of high temperatures, gas evolution, and particulates. However, extended periods of oxygen lancing can increase refractory wear and oxidation of the bath but at the same time increase the production rate.

During the meltdown, phosphorus, silicon, manganese, carbon, and other elements in the scrap metal are oxidized. Slag formation begins and is carefully monitored during the meltdown stages to control the chemical concentration and product quality. Basic EAF's use either single or double slagging operations depending upon the desired quality of the end product. The single slagging process uses an oxidizing slag that is formed by the addition of lime and coke breeze (or other source of carbon) during the initial scrap metal charge. Other flux additions, such as fluorspar, silica, and ferrosilicon, may be made through the slag door. The carbon reacts with the calcium in the slag to form calcium carbide, which makes the slag basic.[22] The oxidizing treatment under a basic slag removes most of the phosphorus and carbon from the melt, thus lowering the concentrations to the desired level.[24]

The double slagging process develops as oxidizing slag first, followed by a reducing slag. The initially formed oxidizing slag is raked off, with the power to the electrodes cut off, and is followed by additions of burnt lime, powdered coke, fluorspar, silica, sand, and ferrosilicon.[21] The purposes of the reducing slag are: (1) to return the reducible oxides, such as those of manganese, chromium, vanadium, tungsten, iron, etc., from the slag to the metal; (2) to eliminate the sulfur as calcium sulfide; and (3) to finish the steel to the specified composition.[21,24] Prior to the metal tap, the reducing slag is poured off into a slagging pot or onto the ground.

During the meltdown operations, the emissions consist of (1) metallic and mineral oxide particulates generated from the vaporization of iron and the transformation of mineral additives; (2) some carbon monoxide from combustion losses of the graphite electrodes, carbonaceous additives, and the carbon content of the steel; and (3) hydrocarbons from the vaporization and combustion of oil and impurities remaining on the scrap charge.[24] Fluoride and trace constituents, such as nickel, hexavalent chromium, lead, cadmium, and arsenic, are emitted from EAF's.[26,27] The carbon monoxide is combusted where the exhaust gases are exposed to ambient air, i.e., the electrode ports and the off-gas duct.

During the melting process, emissions escape through the electrode holes, the slag door, the roof ring, and sometimes the tap spout. Furnace evacuation with direct-shell evacuation control (DEC) can control most of these emissions by maintaining a slightly negative pressure within the furnace. Emission capture and control techniques will be discussed in Chapter 4.

3.2.1.1.3 Tapping. After the proper temperature has been reached and the steel composition has been adjusted, the molten steel is tapped from the furnace into a ladle. To tap a heat, the power is shut off and the electrodes are raised sufficiently to clear the bath. The furnace is tilted (sometimes as much as 45 degrees), and the molten steel is tapped into a ladle. The ladle is placed close to the tapping spout to capture the batch of steel without excessive splashing and to reduce the exposure of the molten steel to the air and thus minimize excessive oxidation and cooling of the steel. Additions of ferromanganese, ferrosilicon, and aluminum are sometimes made to the ladle to adjust the oxygen content of the steel.[21] Depending upon the final product requirements, various alloying agents can also be added to the ladle. These alloying agents include aluminum, titanium, zirconium, vanadium, and boron.[21,22] Specific amounts of alloys are added manually to the molten steel stream during the tap. For certain steel alloys, chrome is added just prior to the tap to avoid oxidation of the chromium during meltdown.[22] During tapping, fumes consisting of iron oxides are generated in addition to oxide fumes resulting from alloys that were added to the ladle. After the molten steel is tapped into the ladle, the ladle is transferred to either an ingot teeming area, a continuous caster, or a refining vessel (in a specialty steel shop).

The bottom-tapped EAF, recently introduced in West Germany, is a technological change in the use of EAF's. Only one bottom-tapped furnace is in operation but the cost-saving aspects may be an impetus for worldwide distribution of these furnaces. This bottom-tapped furnace was built by Mannesmann-Demag Metallgewinnung of West Germany to enable the installation of water-cooled panels further down the furnace sidewall.[16] The company claims that money is saved through reduced capital investment, operating costs, refractory consumption, repair and maintenance, electrode usage, and pollution control expenses. In this furnace, when the metal has been melted and is ready to be tapped, a closing flap is swung out of the way, and the sinter plug is pushed out by the weight of the molten steel. If the plug does not come out, an oxygen lance is used to remove the plug. The molten steel is tapped, then the slag is tapped into a slag pot. Some slag is left in the furnace to protect the refractory from the thermal shock of starting a new melt and the impact of the subsequent charge. Since the furnace does not tilt, electrodes last longer because they are not subjected to stress, and a DEC system is operational during the tap. The greater coverage achieved by larger, water-cooled side panels and a water-cooled roof greatly reduces the refractory replacement requirement.[16]

3.2.1.2 Material Balances. The steel yield from basic refractory electric arc furnaces is relatively high. Approximately 88 to 92 percent by weight of a typical total material charge (i.e., scrap, alloys and fluxes) is returned as product and 8 to 12 percent is poured off as slag or escapes as particulate matter.[28-36] The amount lost as dust varies from 0.6 to 2.9 percent of the metal charged.[37] Figure 3-5 provides a general diagram of the material balance for steel production from an EAF. The amount of particulate matter collected varies from 7.5 to 20 kg/Mg (15 to 40 lb/ton) of steel produced.[36] The remainder of the lost metal is poured off with the slag. Table 3-6 provides a summary of the typical material balance for EAF's and AOD vessels.

The rate of electrode consumption is approximately 5 kg/Mg (10 lb/ton) of steel produced.[37] Many factors affect the rate of electrode consumption, including the operating conditions, the amount of refining performed in the EAF, and the pressure within the furnace. Electrode consumption is a source of hydrocarbon, carbon monoxide, and carbon dioxide emissions.

3.2.1.3 Energy Considerations. Unless scrap preheating is employed, only electrical energy is used in EAF operation. The largest percentage of energy is used during the melting and refining of the scrap charge, and some electricity is used to operate cranes, fans, pumps, and emission control equipment. Natural gas may be used to keep the refractories on idle ladles and furnaces at the desired temperature.

The amount of energy consumed by the EAF varies from 1,647 to 2,614 megajoules per megagram (MJ/Mg) (416 to 660 kilowatt-hours/ton [kWh/ton]) of steel produced.[32-36,38-42] The amount of electricity consumed depends upon the makeup of the scrap, the size of the furnace, the final temperature desired, and the quality of the steel produced. The amount of energy consumed per megagram of steel produced will not change significantly even if scrap preheating is used. Preheating scrap is done primarily to raise scrap temperature so that the meltdown time is decreased. Preheating also drives off superficial water and burns oily material and other combustible contaminants so that fewer emissions are generated during charging and less slag is formed.

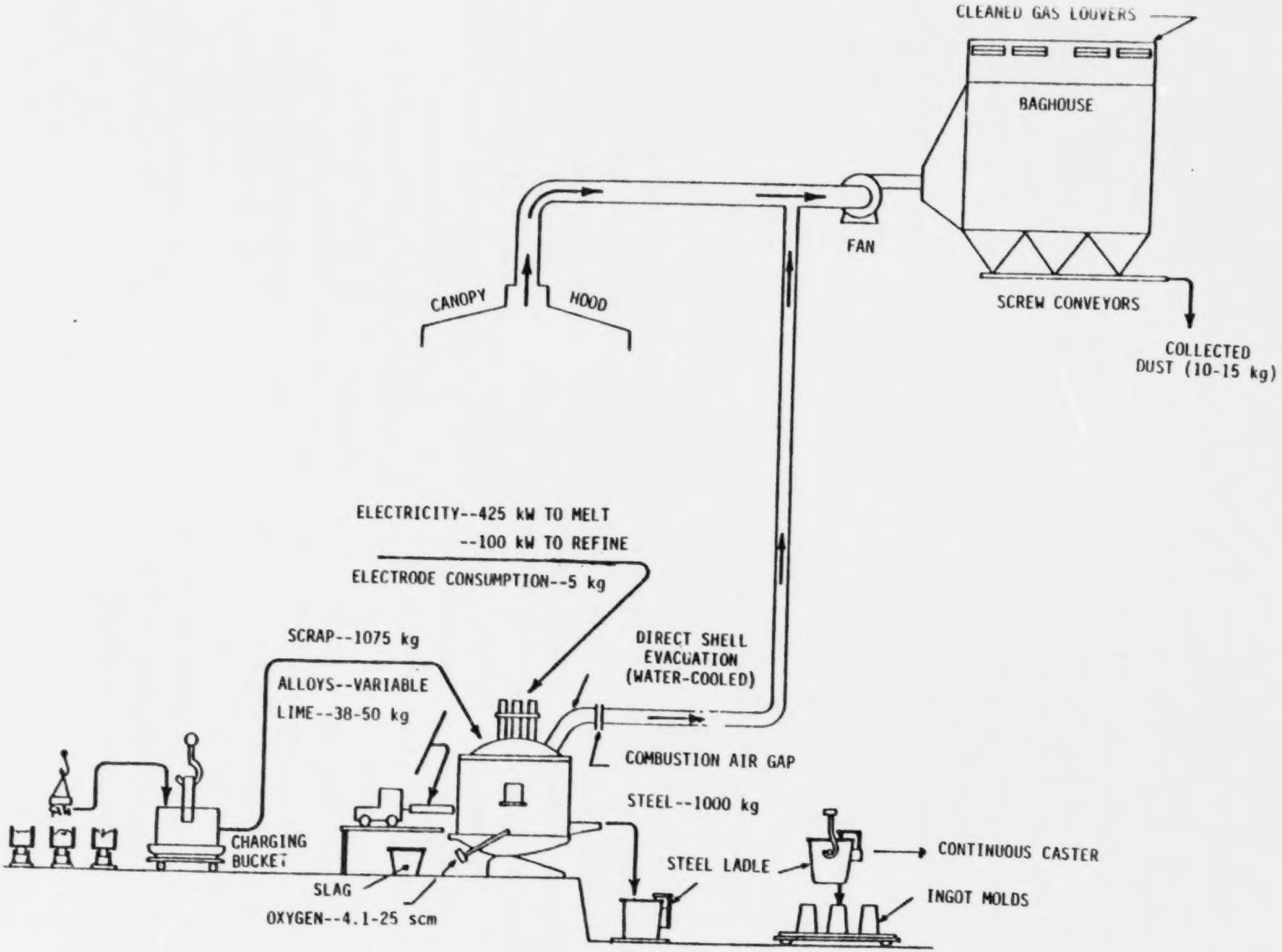

CLEANED GAS LOUVERS
BAGHOUSE
FAN
SCREW CONVEYORS
COLLECTED DUST (10-15 kg)
CANOPY
HOOD
ELECTRICITY--425 kW TO MELT
--100 kW TO REFINE
ELECTRODE CONSUMPTION--5 kg
SCRAP--1075 kg
ALLOYS--VARIABLE
LIME--38-50 kg
DIRECT SHELL EVACUATION (WATER-COOLED)
COMBUSTION AIR GAP
STEEL--1000 kg
CHARGING BUCKET
SLAG
OXYGEN--4.1-25 scm
STEEL LADLE
CONTINUOUS CASTER
INGOT MOLDS

Figure 3-5. Material balance of electric arc furnace based on 1000 kg of steel produced.[37]

TABLE 3-6. RAW MATERIALS AND PRODUCTS--EAF AND AOD OPERATIONS[28-32] (Factor)[a]

Steel type	Common		Specialty			
Furnace type	EAF		EAF		AOD	
Raw Materials						
Metallics	Scrap (Nos. 1 & 2 bundles, rail-scrap, butt ends, shredded, pit scrap, etc.)	(0.93)	Scrap (Stainless steel, chrome-nickel, low carbon steel, low phosphorus steel, iron ore, etc.)	(0.64)	Molten metal	(0.86)
Additives	Lime Carbon FeSi SiMn HiCFeMn Other	(0.05) (0.002) (0.002) (0.01) (0.005) (0.005)	Lime HiCCr Ni Other	(0.05) (0.19) (0.05) (0.07)	Lime, carbon, aluminum, iron, 18-8, HiCCr, MoOx, FeSi, Nickel, MnSi, HiCMn, Mn, other	(0.14)
TOTAL		(1.0)		(1.0)		(1.0)
Products						
Steel	Steel (Rebar, tubing, plates, pipe, structural shapes, rounds, etc.)	(0.88)	Molten metal	(0.88)	Steel (Stainless, silicon, tool and die, low alloy, high temp. alloys, high speed, valve, etc.)	(0.91)
By-products	Slag Dust	(0.10) (0.02)	Slag Dust	(0.10) (0.02)	Slag Dust	(0.08) (0.01)
TOTAL		(1.0)		(1.0)		(1.0)

[a] Factor designates portion of total in material balance (i.e., raw material → product + by-product).

The kilovolt-ampere (kVA) rating of the furnace transformer generally increases with the size of the furnace. If water-cooled panels are used, the voltage applied to the EAF electrodes can be increased without detrimental effects on the furnace refractories. Refractory wear increases at a rate proportional to the increased production rate when water-cooled panels are not used.[16]

3.2.2 Argon-Oxygen Decarburization Vessels and Their Operation

The argon-oxygen decarburization process was first developed by the Linde Division of the Union Carbide Corporation at their Niagara Falls facility.[5] Joslyn Stainless Steel in Fort Wayne, Indiana, assisted in the process development and started a full-scale AOD vessel operation in 1969. Computer techniques assist in optimizing the AOD vessel operation. The AOD process is used to produce tool-and-die steels, high-speed and forging steels, as well as stainless steel and other alloy steels.[5]

The AOD vessel is used in conjunction with an EAF in specialty steel shops. The AOD vessel is used to refine the steel that was melted in the EAF, thus allowing the EAF to be used solely as a scrap melter, resulting in quicker heats. The AOD vessel refines the steel quicker and more economically than an EAF. The AOD vessel is a significant source of air pollution emissions and is frequently ducted to the same control device as the EAF.

Argon-oxygen decarburization vessels are closed-bottom, refractory-lined, pear-shaped converter vessels with submerged tuyeres in the lower portion of the vessel (Figure 3-6). The AOD vessel is constructed of welded steel plate and mounted such that it may pivot for charging, slagging, and tapping. Argon, oxygen, and/or nitrogen gases are blown through the tuyeres into the molten steel to adjust the bath chemistry. The gases are introduced at various ratios of argon/oxygen/nitrogen at various stages of the heat to control the metallurgical reaction, control the bath temperature, and cool and maintain the air passage in the shrouds and tuyeres. Computer controlled orifice meters or vortex precision meters are used to control the gas flow rates and mixtures chosen by the AOD vessel operator.

3.2.2.1 Vessel Operation. The molten steel from an EAF is transferred by ladle to the AOD vessel, which rotates forward to accept the molten

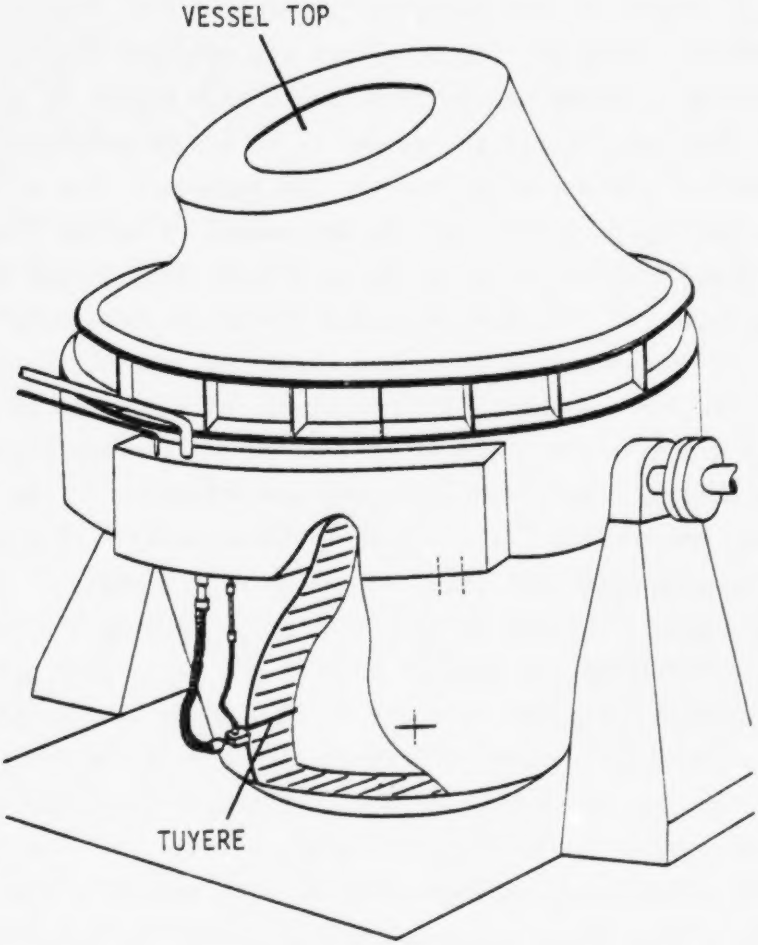

VESSEL TOP
TUYERE

Figure 3-6. Argon-oxygen decarburization vessel.[5]

charge. When the charging operation is complete, typically in 1 to 8 minutes depending on the size of the AOD vessel, it is rotated back to an upright position so that refining can begin.[32-34] Before refining begins, additives such as lime or alloys are added to the molten steel with a crane-held charge pan or through a charge chute.

To begin a heat, while the vessel is in a horizontal position, small volumes of air are blown through the tuyeres in the sides of the vessel for cooling purposes. As the AOD vessel is turned into an upright position, argon is blown through the tuyeres as they become submerged. The argon-oxygen ratio is approximately 1:3 at the beginning of a heat, and the argon concentration is raised throughout the heat until the final ratio is 3:1. In many AOD operations, nitrogen gas is used in addition to argon, since nitrogen is less expensive than argon. However, for some specialty steels, the nitrogen concentration in the steel must be kept low, and nitrogen is not used in these heats.[5] The process gas flow rates depend upon heat size and design of the vessel. The gas consumptions vary from shop to shop with argon fluctuating from 9.9 to 19.6 cubic meters/megagram (m^3/Mg) (390 to 770 cubic feet per ton [ft^3/ton]) of steel produced, nitrogen from 2.8 to 13.7 m^3/Mg (112 to 540 ft^3/ton), and oxygen around 18.8 m^3/Mg (700 ft^3/ton).[32,34,42] Refining is accomplished by blowing argon, oxygen, and/or nitrogen gases through the molten steel bath. The control of the gas mixture and flow is important to avoid the oxidation of alloys necessary for specialty steel production. Refining in an AOD vessel generates a dense cloud of emissions with a strong thermal driving force. As the heat progresses, alloys and fluxing agents are added to the molten steel in quantities that are determined by the chemical analyses performed on samples of the bath. The fluxing agents are typically lime and fluorspar, and the alloys include aluminum, chrome, nickel, manganese, boron, silicon, vanadium, and titanium. Limited amounts of scrap generated at the steel mill (home scrap) may also be periodically added to the vessel as additives to help reach the desired chemical makeup of the final product.

The carbon-chromium equilibrium relationship is very important in controlling the quantity of chromium in the final product. The amount of chromium in the melt is in an equilibrium relationship with the carbon. The carbon level is decreased with oxygen blowing; however, any excess chromium may also be oxidized and lost. The amount of chromium that the melt can retain decreases as the carbon content of the melt decreases. Before the AOD vessel was used, the carbon level was reduced by oxygen lancing in the EAF, and expensive low-carbon ferrochrome was added at the end of the heat.[5] The carbon-chromium relationship (Figure 3-7) determines the extent to which decarburization (carbon removal) will occur before the chromium is oxidized.[5] Raising the temperature of the melt will lower the limits of decarburization without reducing the chromium content. However, the increased temperature has a detrimental effect on furnace refractories. If an inert gas is injected into the AOD vessel along with oxygen, the partial pressure of the carbon monoxide gas is reduced and the carbon monoxide is diluted. These two conditions increase the rate of the decarburization process while greatly increasing the amount of chromium that is retained in the molten steel.[5]

The oxygen flow rate is programmed to maintain the bath temperature through an exothermic reaction. Oxygen is also used to reduce the carbon content of the bath.[6] Just prior to the tap, pure argon is blown through the molten bath to assure uniform temperature distribution and to reduce the bath temperature (for improved steel quality) by decreasing the dissolved gas and oxide content.[5,6] Furthermore, the argon is blown through the molten steel to perform effective mixing of the slag and steel in order to reduce metallic oxides from the slag and to decrease the dissolved gas, oxide and sulfur levels of the molten steel.

3.2.2.2 Material Balances. The steel yield from an AOD vessel is very high. About 91 percent by weight of a typical charge of molten steel and fluxes to an AOD vessel is returned as product (specialty steel).[28,32,34] The metallic yield, i.e., the steel tapped as a percent of the metal charge, is approximately 97 percent. Table 3-6 presents a summary of the material balances for AOD vessels along with EAF's. In specialty shops, the EAF molten steel is typically of a higher grade than that produced in common steel shops; however, to reach the desired concentrations of alloys in the final product, several alloy additions are made throughout the heat. The typical quantity of steel charged

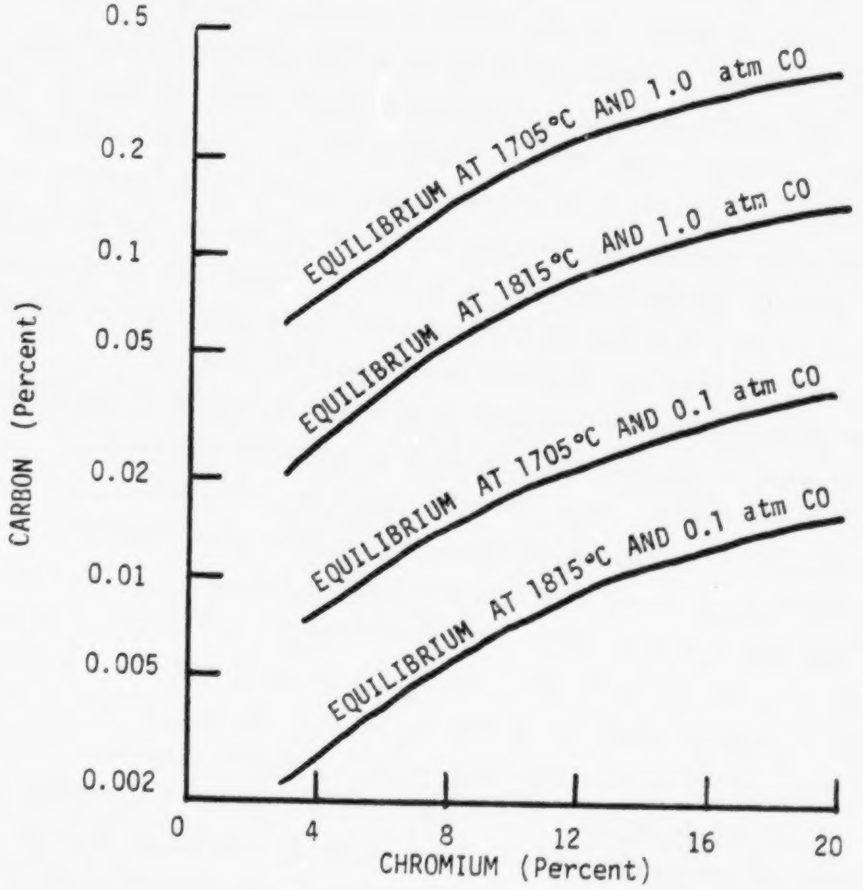


Figure 3-7. Carbon-chromium equilibrium curves.[5]

that is lost as dust is 8.0 kg/Mg (16.0 lb/ton), and the remainder of the lost metal is poured off with the slag.[26,27]

3.2.2.3 Energy Considerations. The main source of energy for refining the molten metal in the AOD vessel is the exothermic oxidizing reaction that is promoted by the injection of oxygen gas. Energy is required only to operate the compressors that inject the gases and to operate the tilting mechanism for the vessel. Furthermore, some electricity is used to operate cranes, fans, pumps, and the emission control system.

3.2.3 New Technology

Technological changes and improvements are continually being made to improve the speed, cost effectiveness, and flexibility of EAF steelmaking. Several of the changes that are being introduced at the time of preparation of this document are listed below. These changes will need to be addressed when the next review of the NSPS occurs. No emissions data are available for any of the described changes because of their relative newness in this county and their limited usage at this time.

One of these changes is the use of DRI in the production of steel. This relatively new technology is not being used to a great extent at present because of low scrap prices and the high cost of producing DRI; however, it could see more use in the future. The fugitive emissions from charging would be greatly reduced because the DRI would be continuously fed into the furnace. The quantity of dust generated will have to be determined because no plants using DRI were observed during this study.

Recyling of the EAF and AOD dust is presently practiced by many stainless steel producers for the recovery of nickel, chromium, and iron. In addition, several EAF plants have their dust recycled for the zinc content or pelletize the dust and feed it back to the furnaces. Numerous studies are underway to explore all possible means of recycling the dust to reduce the loss of iron oxides and valuable alloys and to reduce the impact of the Resource Conservation and Recovery Act (RCRA) requirements. Recycling the dust will help offset some of the costs for pollution control equipment.

Energy recovery is also being attempted on a trial basis at several steel mills. The energy is recovered from the water that circulates through the water cooled roof and well panels.[43] The approximate amount of the energy in the water cycled through the furnace wall panels and furnace roof approaches 16 percent of the total energy input.[44] In addition to this, some of the heat from AOD vessel off gases can be salvaged with a heat exchanger. The energy could be used for heating purpose within a melt shop or in buildings near the melt shop. The recycled heat will improve the overall economy of EAF's and AOD vessels.

New ways to utilize EAF's are currently being investigated. One of these techniques, the bottom tapped EAF, has already been discussed. This type furnace would require a smaller capital outlay and it would be easier to control the air pollution emissions since the tapping emissions of the furnace could be captured with the primary emission capture systems. Another change to the furnace that is receiving experimental use is the use of greater power to the furnace, raising the transformer rating to nearly 1 MVA per megagram of furnace capacity.[16] This would reduce the heat times below those used in existing ultra-high powered (UHP) furnaces.

New methods or combinations of methods for refining the steel from EAF's, in addition to the use of AOD vessels, are currently being introduced. These secondary refining processes, collectively known as ladle refining, are being used to reduce the amount of refining that is performed in the EAF, allowing the EAF to be used strictly as a metal melting device. Argon bubbling is one technique where a gentle stream of argon is injected through a porous plug at the bottom of the ladle. This technique improves the quality of the steel and controls the composition of low-alloy and medium alloy grades of steel.[44] Another technique is vacuum-oxygen decarburization (VOD) that is used to reduce the carbon content in the steel without oxidizing the chromium. A consumable oxygen lance is inserted into the molten steel through the ladle cover. While the ladle is under reduced pressure, oxygen is blown into the melt. After the desired amount of oxygen is blown, the vacuum is continued while argon is bubbled through the melt so that the oxygen remaining in the steel can react with the remaining carbon. This technique takes 2 to 2.5 hours to refine the molten steel.

Vacuum arc degassing (VAD) is another ladle refining technique. The ladle cover is equipped with three electrodes that heat the molten steel to 1680°C (3050°F). After the molten steel reaches the desired temperature, the heat is degassed, desulfurized (after the lime and spar fluxes are added to the molten steel), and alloy corrections are made.[45] Holding the steel under low pressure with argon stirring serves to promote the oxidation of unwanted carbon and to purge the hydrogen gas. This ladle refining technique also requires 2 to 2.5 hours. Desulfurization can also be performed by the lance injection method, in which desulfurizing reagents are pneumatically injected deep into the bath.[45] This method is performed with the ladle under reduced pressure and while argon gas is bubbled through the molten steel. The advantage to this technique of desulfurization is the short treatment time of 5 to 10 minutes.

3.3 EMISSIONS

3.3.1 General

The quantity and type of emissions from an electric furnace depend upon many factors: furnace size, type and composition of scrap, quality of scrap, type of furnace, process melting rate, number of backcharges, refining procedure, and tapping duration and temperature.[24] The majority of the emissions from EAF's are particulates, both ferrous and nonferrous oxides. Furnace emissions are the highest during meltdown and refining operations, but charging and tapping emissions can also be significant, especially if ladle additions are made during the tap and dirty scrap is charged. The charging and tapping emissions represent approximately 5 percent each of the total emissions during a heat.[24] Increases in electrical power to the furnace and the use of oxygen lancing will cause emissions to increase during meltdown and refining.

Electric arc furnace emissions are classified as process or fugitive. Emissions generated at the furnace during periods when the furnace roof is closed (e.g., during melting and refining) and the primary emission capture device (e.g., DEC system, side draft hood) is operative are considered to be process emissions. Those emissions generated during periods when the furnace roof is open (e.g., charging) or when the primary emission capture device cannot operate (e.g., charging and tapping) are considered to be fugitive emissions.

The emissions from an AOD vessel are primarily particulates of both ferrous and nonferrous oxides. The quantity and type of emissions from an AOD vessel depend upon several factors: the quality of the molten steel charge, the quality of the final product desired, and the types and quantity of alloys added. Almost all the emissions occur during the blowing (refining) stage, with the greatest emissions occurring when the concentration of oxygen in the gas stream is the highest at the beginning of the heat. When the AOD vessel is in a tilted position for temperature checks and sample-taking, there are almost no emissions because no gases are blown through the molten steel. The charging and tapping emissions are minimal because the charge is made to an empty vessel, and the tap occurs after the carbon content has been greatly reduced. Table 3-7 presents a summary of the emission factors for EAF's and AOD vessels. Table 3-8 presents a summary of the trace constituent emission factors.

The chemical composition of the typical EAF fume during various stages of a melt is presented in Table 3-9. Iron oxide is the main component of the EAF fume, with a large amount of calcium oxide emitted during refining and a large amount of manganese oxide emitted during charging. The exhaust gas particulate composition for both EAF's and AOD vessels is presented in Table 3-10. The distribution of the particulate matter in EAF and AOD vessel fumes indicates that the particles are quite small. A particle size distribution is presented in Table 3-11. A majority of the particulates are in the inhalable size range (less than 15 micrometers [μm]).

3.3.2 Baseline Emissions

The baseline emission level is the level of emission control reached by the furnace shop in the absence of additional standards. The baseline is used to evaluate the incremental environmental, economic, and energy impacts associated with the regulatory alternatives selected for analysis. The baseline emission level for EAF's is the existing new source performance standard (NSPS).

TABLE 3-7. PARTICULATE MATTER EMISSION FACTORS (UNCONTROLLED)[1,24,26,27,36]

	EAF's		AOD vessels[a]	
	kg/Mg	lb/ton	kg/Mg	lb/ton
Melt and refine	7.5-20	15-40	8.0	16.0
Charge and tap[b]	0.8-1.0	1.6-2.0	--	--

[a] Draft test data, includes charge and tap emissions.
[b] With alloys added to ladle.

TABLE 3-8. TRACE CONSTITUENT EMISSION FACTORS (UNCONTROLLED)[1,25,26,36]

Constituent	EAF's		AOD vessels		EAF's and AOD vessels controlled together	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Carbon monoxide	0.26-3.3[a]	0.52-6.5	--	--	--	--
Nitrogen oxides	0.05	0.1	--	--	--	--
Sulfur oxides	0.005	0.01	--	--	--	--
Fluoride	0.002-0.35[b]	0.004-0.7	0.13	0.27	0.37	0.74
Chromium	--	--	0.43	0.87	0.31	0.61
Lead	--	--	0.019	0.039	0.066	0.13
Nickel	--	--	0.19	0.38	0.13	0.25

TABLE 3-9. CHEMICAL ANALYSIS OF ELECTRIC ARC FURNACE DUST BY PHASE OF FURNACE OPERATION[22]

	Dust composition (percentage)								
Phase	SiO_2	CaO	MgO	Fe_2O_3[a]	Al_2O_3	MnO	Cr_2O_3	SO_2	P_2O_3
Melting	9.77	3.39	0.46	56.75	0.31	10.15	1.32	2.08	0.60
Oxidizing	0.76	6.30	0.67	66.00	0.17	5.81	1.32	6.00	0.59
Oxygen lancing	2.42	3.10	1.83	65.37	0.14	9.17	0.86	1.84	0.76
Reduction	Tr.	35.22	2.72	26.60	0.45	6.70	0.53	7.55	0.55

[a] The iron content was determined as total iron and coverted to Fe_2O_3.

TABLE 3-10. EXHAUST GAS PARTICULATE MATTER COMPOSITION[22,26,27,32,46] (Percent)

Constituent	Process EAF[a]	 AOD[b]
Fe_2O_3	19-53	--
CaO	3-14	7.4
Al_2O_3	1-13	1.6
SiO_2	0.9-9	8.9
MgO	2-15	3.2
Mn_2O_3	0.6	--
ZnO	0-16.3	3.4
NiO	0-3	3.1
Cr_2O_3	0-14	11.4
CuO	0.1	--
MnO	0.6-12	15.6
WO_3	--	0.2
MoO_3	--	0.9
Cu_2O	--	0.4
Cl	1.2	0.4
V_2O_5	--	0.1
TiO_2	--	0.8
PbO	0-4	1.2
Nb_2O_3	--	0.1
FeO	4-10	34.4
C	--	1.7
P	--	0.1
S	--	0.7
Na_2O	1.5	--
LOI[c]	4.3-6.8	--
Other	4.8	3.9

[a] Carbon steel.
[b] Specialty steel.
[c] Loss on ignition.

TABLE 3-11. SIZE DISTRIBUTION OF PARTICULATE MATTER EMISSIONS FROM STEELMAKING EAF AND AOD FACILITIES[22,26,27]

Particle size range, μm[a]	Size distribution, percent by weight		
	EAF	EAF + AOD	AOD
<0.5	--	49	15
0.5-1.0	57-72	8	22
1.0-2.5	--	10	29
2.5-5.0	--	7	10
5-10	8-38	6	5
10-20	3-8	20[b]	19[b]
20-40	2-15	--	--
>40	0-18	--	--

[a] Particles smaller than 15 μm are considered to be respirable or in the respirable categories.

[b] Larger than 10 μm.

The existing NSPS is defined below:

1. Particulate emission limit, 12 mg/dscm (0.0052 gr/dscf)*;
2. Opacity limit from control device, <3 percent (based on a 6-minute average);
3. Opacity limit from shop, zero percent, except:
    a. During charging, the opacity could be greater than zero but less than 20 percent (based on a 6-minute average);
    b. During tapping, the opacity could be greater than zero but less than 40 percent (based on a 6-minute average); and
4. Opacity limit from dust handling system, <10 percent (based on a 6-minute average).

Process weight regulations are commonly used to determine regulations for sources of particulate matter emissions such as AOD vessels. The emission level for AOD vessels, which are not regulated by the existing NSPS for EAF's, is the emission rate determined by one of the process weight equations listed below:

1. $E = 4.10\ P^{0.67}$ for $P \leqq 30$

   $E = 55\ P^{0.11} - 40$ for $P > 30$
2. $E = 3.59\ P^{0.62}$ for $P \leqq 30$

   $E = 17.31\ P^{0.16}$ for $P > 30$

In equations 1 and 2,

P = process weight rate in tons of raw material input per hour

E = allowable particulate emission in pounds per hour

Table 3-12 presents a summary of the air pollution regulations for the States that have steel mills with AOD vessels. In addition to the process weight regulations, most States have a visible emission regulation. Typically, sources are required to maintain less than 20 percent opacity except for one 3- to 6-minute period every hour when average opacity readings can be as high as 40 or 60 percent. Fugitive emission levels are also controlled by most States. Typically, no visible emissions from fugitive sources are allowed at the property line.

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*mg/dscfm = milligrams per dry standard cubic meter.
gr/dscf = grains per dry standard cubic foot.

TABLE 3-12. SUMMARY OF STATE AIR POLLUTION REGULATIONS

EPA region	State	Particulate regulation	Application	Emission limit (lb/h) for indicated vessel size (tons/h) 16.7	66.7	Opacity regulation (percent)	Air pollution regulation reference
II	Connecticut	Equation set 1[a]	b	20.6	33.9	<20, exception	Sec. 19-508-18, 1980
		Controlled to extent reasonable	c			0 at lot line	
V	Illinois	Equation set 2[d]	f	11.4	23.9		Rules 202 and 203, 1980
		Equation set 3[e]	b	27.0	47.3	≤30, exception	
		No visible emissions	c			0 at lot line	
V	Indiana	Equation set 3	g	27.0	47.3	≤40, exception	Regulations APC 3 and 5, 1980
III	Maryland	PM ≤0.03 gr/dscf[h]	g	i	i		COMAR 10.18.10, 1980
		Controlled to extent feasible	c				
V	Michigan[j]	Equation set 3	g	27.0	47.3	≤20, exception	Part 3, 1980
II	New York	PM ≤0.15 gr/dscf	b	i	i	≤20	Sec. 216, 1979
		PM ≤0.05 gr/dscf	f	i	i	≤20	
V	Ohio	Equation set 2	g	11.4	23.9	<20, exception	Regs. 3745-17-07, 3745-17-08, 1977
		Controlled to extent reasonable	e			Same	
III	Pennsylvania	Equation set 4[k]	b	11.6	20.9	<20, exception	Secs. 123.13, 123.41, 1979
		PM ≤0.04 gr/dscf[k], exception[l]	g	i	i		
		No emissions	c				
X	Washington	PM ≤0.10 gr/dscf	g	i	i	≤20, exception	Regs. WAC 173-400-040, WAC 173-400-060, 1976
III	West Virginia	Table[m]	b	24.0	34.3	≤1 on Ringleman scale	Ad. Reg. 16-20
		Controlled to extent reasonable	c				

[a] 1: $E = 3.59\ P^{0.62}$ $P \leq 30$
$E = 17.31\ P^{0.16}$ $P > 30$
where E = particulate emission rate in lb/hour
P = process weight rate in tons/hour

[b] Existing source.

[c] Fugitive emissions.

[d] 2: $E = 2.54\ P^{0.534}$ $P \leq 450$
$E = 24.8\ P^{0.16}$ $P > 450$

[e] 3: $E = 4.10\ P^{0.67}$ $P \leq 30$
$E = 55.0\ P^{0.11} - 40$ $P > 30$

[f] New and modified equipment.

[g] New and existing equipment.

[h] PM = particulate concentration in gr/dscf.

[i] Depends on gas flow rate.

[j] One AOD in Michigan has not been operated since 1977.

[k] 4: $E = 0.76\ R^{0.42}$
where R = F x W
F = process factor, 40 lb/ton of product
W = production or charging rate, units/hour
E = allowable emissions in lb/hour

[l] PM = 6,000 E for 150,000 <E <300,000 dscf
PM = 0.02 gr/dscf for E ≥300,000 dscf
where E = effluent gas volume in dscf/min

[m] Emission limit interpolated from table in State regulation.

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4. EMISSION CAPTURE AND CONTROL TECHNIQUES

4.1 INTRODUCTION

This chapter presents the capture and control techniques for EAF and AOD units. The requirements for emission capture and control equipment vary with each plant's individual design and operating practices. The engineering factors that must be addressed when choosing an emission capture system include the size of the EAF or AOD vessel and the operational practices of the individual furnace or vessel, such as the oxygen blow rate, the type and amount of alloys added, the number of backcharges added to the EAF, the melt rate of the EAF, and the grades of steel produced. The size, layout, and number of openings in the melt shop building have an impact on the choice of which emission capture arrangement and air flow rate will meet the required emission limit at the most favorable cost. The Federal, State, or local emission regulations for each plant will also influence the choice of emission capture equipment.

Control of emissions from EAF's and AOD vessels requires two separate steps: (1) the evacuation and containment (capture) of the emissions and (2) the removal of various pollutants--primarily particulate matter--from the evacuated gas stream (control). Emissions must be captured during the melting and refining processes (process emissions) and the charging and tapping processes (fugitive emissions).

The air pollution capture systems to be discussed in the following sections are compatible with processes used to make the many different grades of steel. Fabric filters are the most widely used control devices to treat the exhaust gases from EAF's. There is one ESP (installed in 1958) in operation at an EAF plant in Cleveland, Ohio. Only one scrubber has been installed on an EAF, and no ESP's have been installed since 1974. Only fabric filters are known to be in use on AOD vessels.

New developments and improvements in the steel industry have resulted in the use of higher air flows per megagram of steel produced to effectively evacuate the process and fugitive emissions. These include the use of UHP EAF's, the use of AOD vessels in specialty steel shops, and shortened heat times in both carbon and specialty steel shops to increase the production rate. These changes have resulted in increased use of large single or segmented canopy hoods and closed roof monitors over the furnace, local tapping hoods, and scavenger systems to capture emissions that bypass the canopy hood. These fugitive emissions capture systems are the most significant improvements over the capture systems that were in use during the development of the existing standards of performance. An alternative to the canopy hood/scavenger duct capture system or closed roof shop is the total furnace enclosure (TFE). Several TFE's have been installed in carbon shops in the past 5 years. These various capture systems are discussed in the following sections.

4.2 CAPTURE OF EAF PROCESS AND FUGITIVE EMISSIONS

Several capture systems are used by the industry to meet the requirements of State and local regulatory agencies and the existing standards of performance for EAF's. These systems include:

1. Direct-shell evacuation control systems;
2. Side draft hoods;
3. Partial furnace enclosures;
4. Total furnace enclosures;
5. Canopy hoods;
6. Tapping hoods;
7. Scavenger duct systems;
8. Shop roof configurations; and
9. Building evacuation.

Each system is described below, along with design and operational factors that affect its performance.

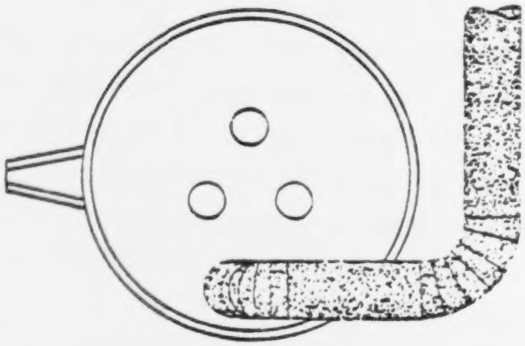
4.2.1 Direct-Shell Evacuation Control System

The DEC system, also known as the fourth-hole evacuation system, requires a hole in the furnace roof in addition to the three holes required for the electrodes. A water-cooled or refractory-lined duct attaches to the furnace roof and, when the furnace roof is in place, joins a duct that is connected with the emission control device (Figure 4-1). At the connecting point of the two ducts, there is a small gap that allows dilution air to enter the duct. The dilution air cools the exhaust gases and causes the combustion of the carbon monoxide and unburned hydrocarbons. The gap also allows room for the furnace roof to be elevated and rotated to the side for furnace charging and for the furnace to be tilted for tapping molten steel or for slagging. During the times when the furnace is tilted or the furnace roof is rotated aside for charging, the DEC system is ineffective, and the fugitive emissions drift toward the building roof or canopy hood.

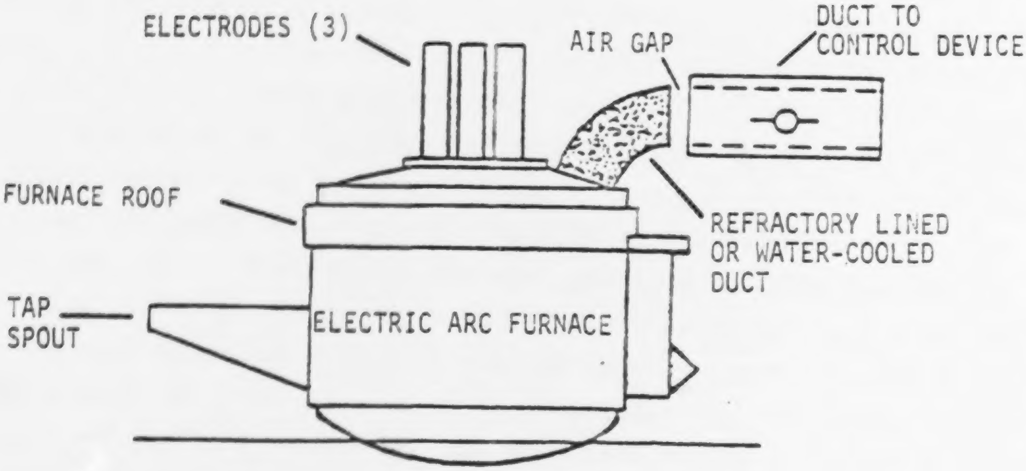
When the furnace roof is in place, the DEC system provides good emission control with a minimum of energy since the air volume withdrawn is the lowest of the process emissions capture devices. During melting and refining operations, a slight negative pressure is maintained within the furnace to withdraw effectively the emissions through the DEC system.

The DEC withdraws between 90 and 100 percent of the melting and refining (process) emissions from the furnace before they escape the furnace and are diluted with ventilation air. A typical particulate matter emission capture efficiency with a properly operated DEC system is estimated to be 99 percent of the process emissions.[1]

The DEC system of fume extraction has been widely used in the steel industry for many years to capture EAF emissions. It can be used on EAF's that produce any grade of steel, including common carbon grades and alloy steel grades. In the past, when EAF's performed both the melting and refining operations, the DEC system could not be used in specialty steel shops when a second or reducing slag operation was performed. The reducing slag was used to remove impurities from the molten steel, and the introduction of outside air into the furnace (due to the negative pressure created by the DEC system) oxidized the slag and rendered it ineffective. With the wide acceptance of AOD vessels and other secondary refining operations (i.e., duplexing, or the use of a vessel other than the EAF in which to carry out refining), the use of a reducing slag has been diminished. Duplexing allows the use of the DEC fume extraction system in most EAF shops.



A. PLAN


ELECTRODES (3)
AIR GAP
DUCT TO CONTROL DEVICE
FURNACE ROOF
REFRACTORY LINED OR WATER-COOLED DUCT
TAP SPOUT
ELECTRIC ARC FURNACE

B. ELEVATION

Figure 4-1. Direct-shell evacuation control (two views).

The direct evacuation system can be retrofitted to an existing furnace. However, careful design is needed to avoid problems such as: excessive weight on the furnace roof of small furnaces, excessive deterioration of shell refractories and roofs, inadequate water cooling, and inadequate clearance for the DEC when rotating the furnace roof for charging.[1,2] The DEC system, however, is very popular in new installations, and no problems are known to exist when the DEC system is built as a part of the new furnace.

4.2.2 Side Draft Hoods

The side draft hood is another fume extraction system that is used on EAF's to capture melting and refining (process) emissions (Figure 4-2). The side draft hood is mounted on the EAF roof, with one side open to avoid restricting the movement of the electrodes. This system requires a tight fit of the furnace roof so that all the emissions that leave the furnace escape only around the electrode annuli. The side draft hood, like the DEC system, operates only when the furnace roof is in place and when the furnace is in an upright position.

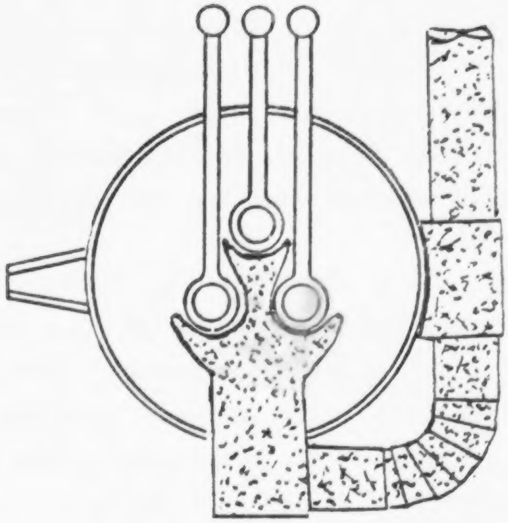
Side draft hoods are not used as widely as DEC systems and, because of higher operating costs, are typically used only on small furnaces.[2] The side draft hood requires a larger exhaust volume than a DEC system.[1] The exhaust volume serves to introduce dilution air to cool the exhaust emissions and ensure combustion of the carbon monoxide and unburned hydrocarbons.

The side draft hood has an estimated particulate emission capture efficiency of between 90 and 100 percent of the melting and refining emissions. The typical particulate capture efficiency is estimated to be 99 percent.[1]

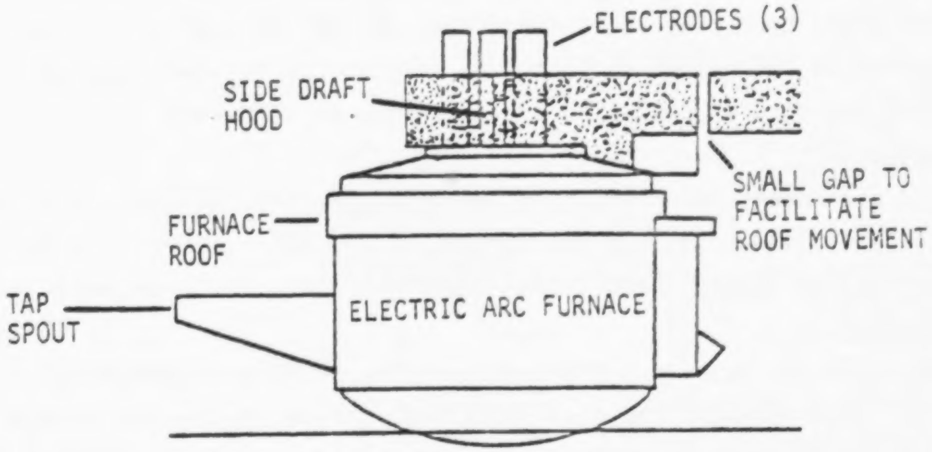
Retrofitting an existing EAF with a side draft hood generally presents few problems. The side draft hood allows easy access to the electrodes and annuli to perform needed maintenance. It is believed that the use of this system on new furnaces will be limited to small furnaces.

4.2.3. Partial Furnace Enclosures

The partial furnace enclosures (PFE's) have walls on three sides of the furnace area that act as a chimney directing the fugitive emissions



A. PLAN



ELECTRODES (3)
SIDE DRAFT HOOD
SMALL GAP TO FACILITATE ROOF MOVEMENT
FURNACE ROOF
TAP SPOUT
ELECTRIC ARC FURNACE

B. ELEVATION

Figure 4-2. Side draft hood (two views).

to the canopy hood. The PFE systems are used in association with a DEC system for process emissions and sometimes with local hoods for the capture of slagging and tapping emissions (Figure 4-3). The walls of the PFE help reduce the impact of cross drafts in deflecting the upward flow of emissions. Significant secondary benefits are that the furnace noise and heat radiation are reduced outside the partial furnace enclosure walls. The enclosure walls are designed to allow adequate room for the furnace roof to swing open for charging, for crane passage above the enclosure, and for furnace maintenance.

Partial furnace enclosures are in use at several steel plants that have EAF's ranging in size from 154 Mg (170 tons) to 204 Mg (225 tons). One company uses PFE's on two 204-Mg (225-ton) EAF's. This system uses a DEC system to capture the process emissions and local hoods above the tapping ladle and slag pot to capture the fugitive emissions from the tapping and slagging operations, respectively. These hoods are stationary, and the molten steel or slag is poured through an opening in the hood (see Figure 4-3).

Two other examples of PFE's are located at new facilities that were completed during 1981. The PFE's were installed on two new 154-Mg (170-ton) UHP EAF's and on two new 168-Mg (185-ton) UHP EAF's.[3,4] Both plants incorporated the furnaces and enclosures into an existing shop when old or damaged equipment was replaced.

Partial furnace enclosures are easier to install and less expensive than total furnace enclosures (Section 4.2.4). Because the furnace is only partially enclosed, the crane operator can see the furnace during charging. Any periodic explosions due to wet or icy scrap will not cause damage to a partial enclosure since the force will be vented out the top and front of the partial furnace enclosure. In contrast to the total furnace enclosure, however, a PFE does not function to capture emissions, but serves to direct them to another capture device. Crane passage above the furnace will still disrupt the emission plume. One plant has partially overcome the problem of the emission plume deflection by installing additional enclosure walls on the crane so that when the crane is in position for a charge or a tap, the enclosure walls extend from the floor to the roof.[5] Retrofitting a PFE into an old shop

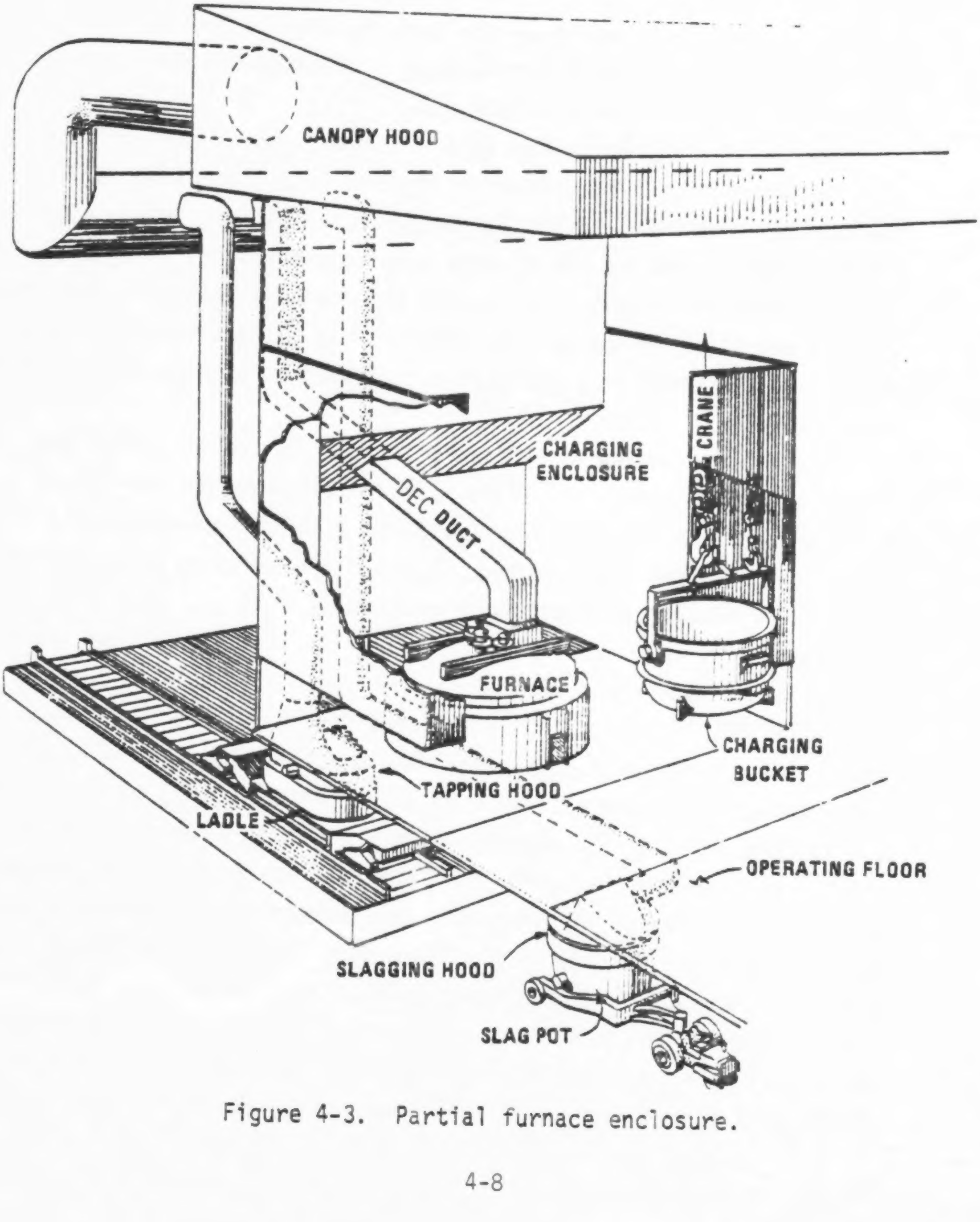

CANOPY HOOD
CRANE
CHARGING ENCLOSURE
DEC DUCT
FURNACE
CHARGING BUCKET
TAPPING HOOD
LADLE
OPERATING FLOOR
SLAGGING HOOD
SLAG POT

Figure 4-3. Partial furnace enclosure.

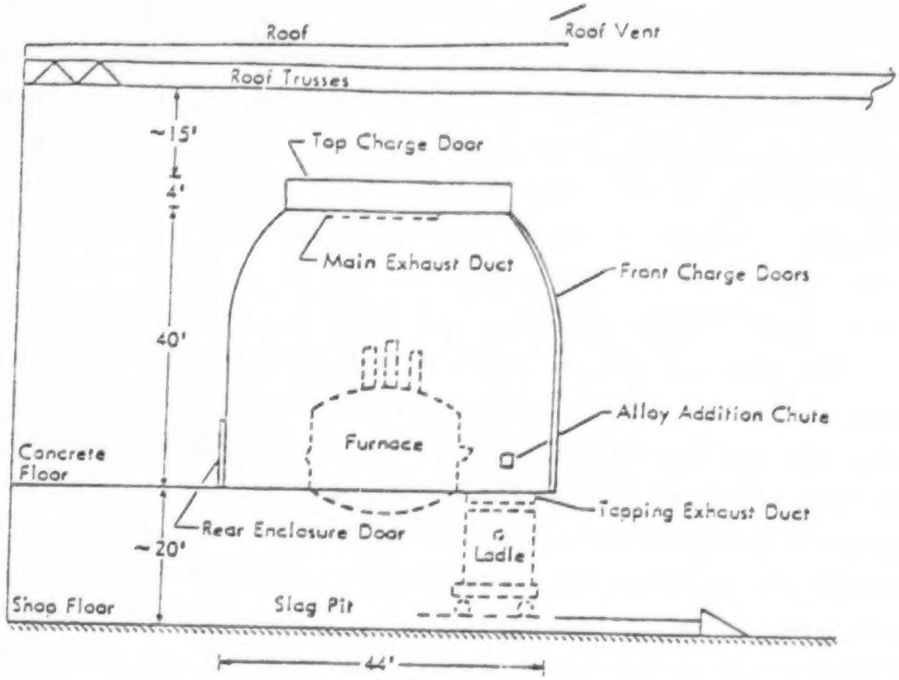
with a new EAF is easier than retrofitting some of the other emission capture systems.

The amount by which PFE's increase canopy hood capture efficiency has not been documented. However, based on their design considerations (i.e, decreased cross-draft problems), their use should increase overall fugitive emission capture by reducing the quantity of emissions that escape capture by the canopy hood. Overall fugitive capture efficiency should be in excess of the 80 percent (estimated) capture efficiency for canopy hoods (see Section 4.2.5).

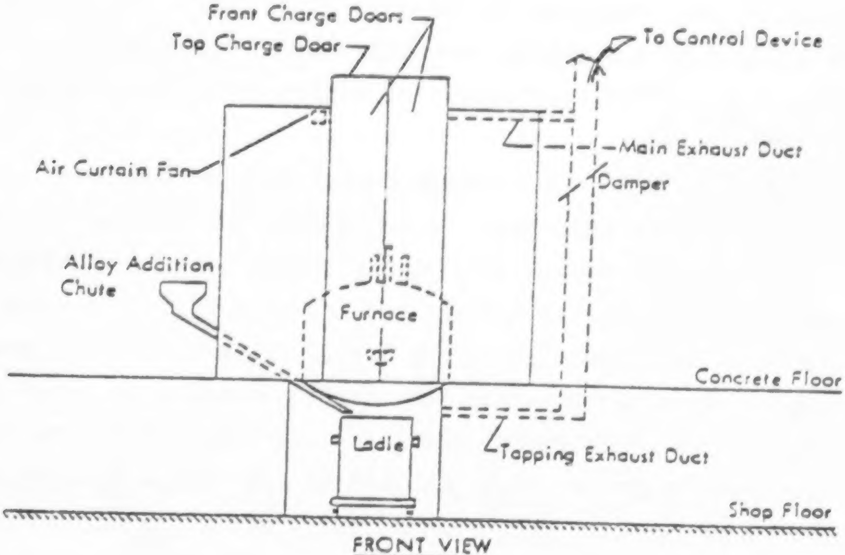
4.2.4 Total Furnace Enclosure

The total furnace enclosure completely surrounds the furnace with a metal shell that acts to contain all the charging, melting and refining, slagging, and tapping emissions as well as to reduce the furnace noise and heat radiation outside the enclosure (Figure 4-4). The enclosure is typically designed to capture all the process and fugitive emissions because the emissions are confined to a small area. Total furnace enclosures operate with a greatly reduced air flow compared with building evacuation or canopy hood systems. The volume of air that must be removed from the total furnace enclosure is estimated to be only 30 to 40 percent of that required for an efficient canopy hood system.[1] A duct at the top of the enclosure removes charging and melting/refining emissions, and a local hood under the enclosure collects emissions from molten steel and slag tapping.

The crane brings in the charge bucket through the front charge doors on the furnace enclosure. A mechanical roof door opens to provide a slot for the crane cables holding the charge bucket. During charging, the front charge doors are closed, and an air curtain blows any emissions directly into the large duct at the top of the enclosure.[3] Some emissions can escape capture through this roof door; therefore, a scavenger duct or a single canopy hood can be installed over the TFE for the purpose of capturing these fugitive emissions. After the charge, the front charge doors are reopened, the charge bucket is removed, the furnace roof is moved into place to begin melting, and the front charge doors are closed. Tapping emissions are collected by diverting (using dampers) part of the


Roof
Roof Vent
Roof Trusses
~15'
4'
40'
~20'
Top Charge Door
Main Exhaust Duct
Front Charge Doors
Furnace
Alloy Addition Chute
Concrete Floor
Tapping Exhaust Duct
Rear Enclosure Door
Ladle
Shop Floor
Slag Pit
44'

SIDE VIEW


Front Charge Doors
Top Charge Door
To Control Device
Air Curtain Fan
Main Exhaust Duct
Damper
Alloy Addition Chute
Furnace
Concrete Floor
Ladle
Tapping Exhaust Duct
Shop Floor

FRONT VIEW

Figure 4-4. Total furnace enclosure at Lone Star Steel Company.

flow from the main exhaust duct to a duct adjacent to the tapping ladle. The tapping ladle is positioned under the furnace by a transfer car.

The first TFE on a domestic furnace was installed in 1976.[1] Total furnace enclosures were installed on each of two 54.4-Mg (60-ton) furnaces. One TFE unit was installed in 1980 on a new steel plant EAF, and three additional TFE's were retrofitted in 1981 onto existing steel plant EAF's.[3,6] An existing DEC system was maintained on the retrofitted furnaces to capture the primary emissions, and the TFE was used to solve a fugitive emission problem. A retrofit TFE was installed on a medium size (165-Mg, 182-ton) furnace with a 22-ft shell in Italy in September 1980.[7] This enclosure is on a furnace considerably larger than any of the furnaces with TFE's in the United States and should provide valuable operational data for the use of TFE's on medium-to-large EAF's.

Proper design of a TFE must include analysis of the size and transformer capacity of the EAF (which have a significant impact on the TFE size and the air flow necessary to evacuate the enclosure), the quality of the scrap used, the oxygen blow rate, the amount of space that is needed inside the enclosure, the number of doors in the sides of the enclosure, and the amount of space above the furnace needed for crane clearance.[5,8] In addition, the need for explosion venting panels to vent the pressure from explosions due to wet or oily scrap must be evaluated.[8]

Industry has shown some reluctance to the use of TFE's. Some crane operators believe that the TFE will hamper operations such as charging and alloy addition since the crane operator will have difficulty getting the bucket into position and will not be able to see the bucket when the charge doors are closed.[3] Another problem that industry considers to be important is that the use of a TFE may cause too many process delays, especially on larger furnaces.[5] Problems with the charge doors leaking have arisen because the seals are degraded by the high heat, and the doors will not open or close when they are bumped and damaged by the charge bucket.[5] Vendor representatives indicate that these problems may be solved after operating exprience has been gained and recommended maintenance is performed.[5,8] Operator reluctance to TFE's is being reduced by the experience gained at domestic and foreign steel plants.[6,7]

Emission capture efficiencies of TFE systems are estimated to range from 90 to 100 percent.[1] The capture efficiency may be enhanced through the use of a canopy hood or a scavenger duct system.

4.2.5 Canopy Hoods

The canopy hood system involves one or more canopy hoods suspended from, or built into, the melt shop roof directly above each furnace (Figure 4-5). The hood has to be high enough to provide clearance for crane movement and space for the upward movement of the electrodes when moving the furnace roof. Canopy hoods are widely used either alone, to capture both process and fugitive emissions, or in combination with other capture technologies to capture fugitive emissions only. This system is one of the oldest and most well-known capture technologies in use. It is likely that canopy hoods will continue to be used, typically in combinations with other capture technologies discussed in other sections of this chapter.

The thermal currents from the hot furnace help the fumes from the charging, melting and refining, and tapping operations rise to the canopy. The fumes are sometimes deflected away from the canopy by impingement on the crane and charge bucket when the furnace is being charged and also by impingement on the crane during tapping when the crane holds the ladle. The emissions can also be disrupted by cross-drafts within the building due to open doors, open ends and side walls of the building, passage of shop vehicles, temperature gradients within the shop, and other hoods that ventilate nearby processes. For small furnaces, the canopy is not generally as effective because there is less thermal uplift generated by the furnace.[1] High-pressure weather systems and low humidity tend to aid efficient upward flow of the exhaust plume. However, during periods of low-pressure weather systems, high humidity, and/or strong winds, the thermal columns above the furnace may be insufficient to carry all fumes directly to the hoods.[1]

Partition walls and air curtains have been successfully employed to reduce the effects of cross-drafts and improve the flow of emissions to the canopy hoods. The partition walls and air curtains can be used to

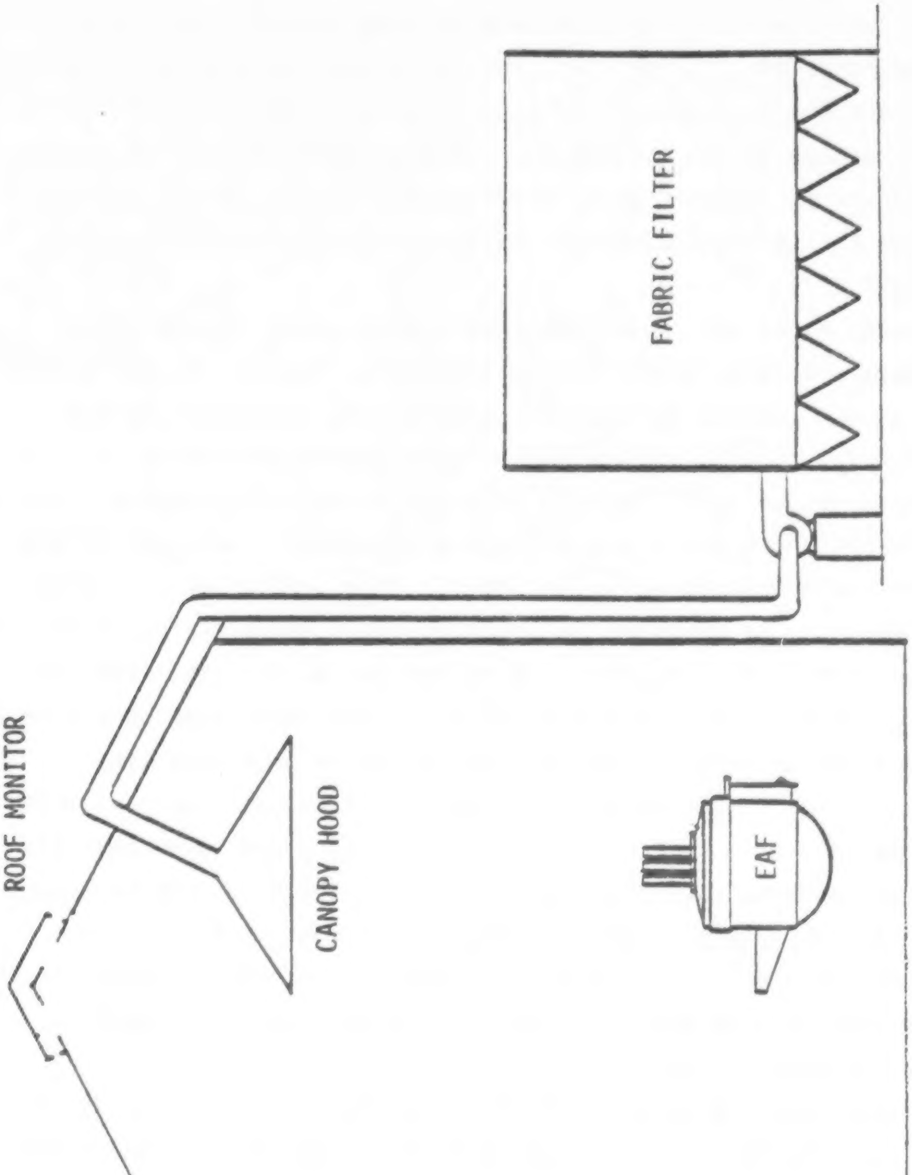

ROOF MONITOR
CANOPY HOOD
EAF
FABRIC FILTER

Figure 4-5. Canopy hood capture system.

screen the steelmaking furnace and help contain and direct the fumes to the canopy. Unfortunately, the air curtain often cannot completely overcome the force of cross-drafts. The emissions that are not completely captured bypass the hood and accumulate in the upper part of the melt shop roof or escape to the outside air. A scavenger duct system can be installed in the exhaust ductwork immediately above the canopy to capture the emissions that elude the canopy and accumulate under the shop roof (see Section 4.2.7).

The canopy hoods can be divided into sections that can be closed off by dampers. At many steel plants, the canopy hood is divided into two sections, one section for charging and melting emissions and the other section for tapping emissions. At some plants the canopy is divided into three sections that are arranged to capture slagging emissions, charging and melting emissions, and tapping emissions. Sections of the canopy hoods can be closed off with dampers, if a particular operation is not in progress, to maximize the draft directly above the point of greatest emissions. Tapping hoods can be located at the same level as the charging canopy hood or directly above the tap ladle (see Section 4.2.6).

Retrofitting an existing furnace with a canopy hood sometimes requires extensive structural modifications. The trusses and roof beams must often be relocated, reconstructed, and strengthened to accommodate the canopy and exhaust ductwork. In some shops, there may not be enough clearance between the crane and the roof, or the roof configuration itself may not be adaptable to a canopy installation. Also, space outside the shop must be available for a baghouse capable of handling the required exhaust volume.

The capture efficiency of a single canopy hood is typically 75 to 85 percent (average 80 percent), depending on the amount of cross-drafts present in the shop. The capture efficiency rises to 85 to 95 percent (average 90 percent) with a segmented (sectioned) or a large canopy hood. These percent capture efficiencies are estimates based on observations made at several facilities, engineering judgment, and review of available technical information.[11-14] Industry representatives believe that there may be trade-offs since the segmented canopy hood has a higher face velocity to capture the fumes while the single canopy hood has greater storage volume.

4.2.6 Tapping Hoods

Tapping hoods have received increased use in recent steel plant emission capture designs. They are used to supplement the emission capture of TFE's, PFE's, canopy hoods, and even DEC and side draft hood systems. (The air flow utilized by a DEC system can be diverted from the DEC during the tap when the DEC is ineffectual.)

The tapping hood can have several different adaptations, but it usually involves a movable or stationary hood that is located immediately above the tapping ladle when the tapping operation is in progress. Movable tapping hoods are swung aside when tapping is not in progress. A hood located right above the ladle is considerably more efficient than a canopy hood at the roof level.[14] In the past, the industry has used the crane to hold the ladle during the tap. The crane deflects the fumes that are generated during the tapping operation, making it very difficult for the canopy hood to effectively capture the emissions. Currently, many shops set the ladle on a pedestal or ladle car prior to tapping, and this eliminates deflection by the crane.

One company has developed a tapping pit enclosure that is simple in design and is efficient. The overhead crane places the ladle in a tapping pit, then a powered, removable cover seals the tapping pit. The molten steel from the EAF is tapped out a short spout to a chute that extends through the side wall of the ladle pit.[1] The exhaust gases are drawn out through a duct at the top of the tapping pit enclosure. The tapping pit enclosure captures 90 to 100 percent of the fumes.[1]

Another design utilizes a retractable hood that can either be manually or automatically operated when the furnace starts to tilt for a tap. The ladle is put in place with the overhead crane, and then the crane is withdrawn before the retractable hood is projected outward so that no damage is done to the hood with the crane hooks. When the furnace starts to tilt, the flow from the DEC is dampered off and redirected to the tapping hood. The capture efficiency of this local tapping hood has not been documented but is expected to greatly exceed that of a canopy hood.

There are other possible designs for tapping hoods, but the primary emphasis is on placing a hood much closer to the source of emissions, thereby eliminating the problems of fume deflection by the crane and emission plume disruption by cross drafts. Because of space limitations, retrofitting a tapping hood can be more difficult than installing such a hood in a new shop.

4.2.7 Scavenger Duct System

A scavenger duct system consists of small auxiliary ducts that are located above the main canopy hood near the shop roof. A relatively low flow rate (approximately 10 percent of the total flow rate for a canopy hood) is maintained through these ducts to capture fugitive emissions that are not captured by the canopy hood system. The ducts have openings through which the fugitive emissions are withdrawn to be cleaned by the emission control device.

The factors that should be considered when designing a scavenger duct system include the estimated capture efficiency of the canopy hoods, the regulatory requirements for fugitive emissions containment, the engineering necessary to install the scavenger system, the shop configuration, and worker health and safety.

The capture efficiency of scavenger ducts is enhanced through the use of cross-draft partitions and can only be used with a closed roof configuration, semi-closed roof (only closed above the furnace area, open elsewhere), or louvered roof.

4.2.8 Shop Roof Configurations

There are three basic shop roof configurations: completely open, open except over the furnace, and closed over the entire melt shop. A variation of the closed roof shop involves a louvered roof monitor that is mechanically controlled to allow for closing the louvers during periods of fugitive emissions and opening the louvers when the melt shop is clear.

Completely open roof monitors allow for natural ventilation within the shop but do not provide adequate residence time for effective emissions capture by a canopy hood and preclude the use of scavenger systems. Those emissions not captured on contact with the capture system (i.e., canopy hood) are emitted to the atmosphere.

A shop roof system that is closed above the furnace but open over other areas provides the advantages of both the open and closed systems. The open monitor sections provide for natural ventilation, while the closed roof section, particularly when combined with cross-draft partitions or a scavenger duct system, aids in effective emissions capture (Section 4.4).

A shop roof system that is closed over the entire shop promotes effective capture of emissions because the emissions are contained within the shop and can be captured by the canopy hood or a scavenger duct system. However, closed roof shops do not allow for natural ventilation and industry claims this may contribute to a worker heat stress problem.[10]

The National Institute for Occupational Safety and Health (NIOSH) has concluded that radiant heat is the primary contributing factor to heat stress. High air ventilation rates may lower the temperature in an electric arc furnace shop to some extent; however, they do not reduce the effects of radiant heat. Other means available to protect workers from heat stress are:[15,16]

1. Decrease the number of workers and the time they are exposured to the heat;

2. Provide an air conditioned rest area to decrease the time-weighted average temperature;

3. Use portable fans to blow air into the work area;

4. Blow air ducted from outside the shop (and possibly cooled) into the work area; and

5. Utilize radiation shields and protective clothing.

There are several recently constructed closed roof shops operating in warm areas of the country, which may indicate that adequate protective measures are available to compensate for the loss of natural ventilation. However, sufficient operating experience has not yet been gained to determine if heat stress at these plants will be a problem.

An optional shop roof configuration for use where heat stress may be a problem is the adjustable or louvered roof monitors described above. These monitors can be closed during periods of high emissions and opened at other times to permit natural ventilation. The effectiveness of this type of system may not be as great for multifurnace shops as it is for single furnace shops because of overlapping periods of high emissions. Sectioning of the shop with cross-draft partitions could alleviate some of the problems encountered with a multifurnace shop. Two EAF shops are known to use the louvered monitor system.

4.2.9 Building Evacuation

A building evacuation system involves a closed shop roof with ductwork at the peak of the roof to collect all emissions from the shop operations. This system of capture is very similar to a canopy hood capture system with a closed roof. Sheet metal partitions can be permanently attached to the shop roof to prevent the emissions from drifting to other parts of the melt shop.

Building evacuation requires a greater air flow than a canopy hood system but will capture all emissions generated in a furnace shop. Some estimates are that building evacuation requires 25 percent more air flow than a well-operated canopy hood. The capture efficiency for the building evacuation system is very good, ranging from 95 to 100 percent removal of the particulate matter; the typical maximum particulate removal efficiency is 99 percent.[1] The emissions capture rate, however, is sometimes slower than that of a canopy hood.

There are several plants utilizing this type of emission capture system. One of these plants has two 22.7-Mg (25-ton) EAF's, a 45.5-Mg (50-ton) EAF, a 68.2-Mg (75-ton) EAF, and a 22.7-Mg (25-ton) AOD vessel. Another plant has one 45.5-Mg (50-ton), one 68.2-Mg (75-ton), and three 90.7-Mg (100-ton) EAF's.

The factors that influence the selection of a building evacuation system over other systems for controlling emissions are:[1,9]

1. Insufficient space and structural limitations that preclude the use of a canopy hood;
2. Desire to control fumes from all EAF operations including charging, melting, refining, slagging, tapping, and other operations in the shop;
3. Roof design well suited to serve as the hood;
4. Desire to exhaust the entire shop's internal atmosphere to reduce pollutant concentrations for worker hygiene; and

5. Only minor interference with existing shop operation would occur when a building evacuation system is installed.

4.3 CAPTURE OF AOD VESSEL PROCESS AND FUGITIVE EMISSIONS

The emissions from the AOD vessel primarily occur when the vessel is in an upright position for blowing or stirring with a combination of argon, oxygen, and nitrogen gases. The emissions during these times are very heavy, but the upward thermal lift quickly brings the emissions to the capture device. The emissions during molten steel charging are minimal since the molten steel is hotter than the refractory and the gas-injecting tuyeres are not in operation. The gas injection is normally stopped before the vessel turns down for alloy and flux additions or for sampling and temperature checks. However, sometimes the gas injection operation is not stopped until the vessel has started to turn down, resulting in emissions that are largely deflected by the overhead crane if it is in position for adding fluxes or alloys. Slagging and tapping emissions are small since the gas injection is stopped to prevent damage to the tuyeres while the vessel is in a horizontal position.

4.3.1 Diverter Stack With Canopy Hood

The diverter stack with canopy hood capture configuration is a common arrangement currently used for collection of emissions from AOD vessels (Figure 4-6). The diverter stack is typically located 1.5 to 3 m (5 to 10 ft) above the mouth of the vessel. The diverter stack can either be fixed in position or movable so that it can swing out of the way during charging and tapping. The diverter stacks that are in a fixed position are typically at a greater distance from the AOD vessel than movable stacks.

The diverter stack is tapered, with the narrow end at the top, and acts to accelerate the AOD vessel off-gases toward the canopy hood. The stack greatly reduces the dispersing effect of melt shop cross-drafts on the upward flow of the emission plume.

The canopy hood is typically built into the shop roof so that adequate clearance is provided for the overhead cranes. The emission capture by canopy hoods is usually very good. However, the emissions can be deflected by the overhead crane or by shop cross-drafts if the

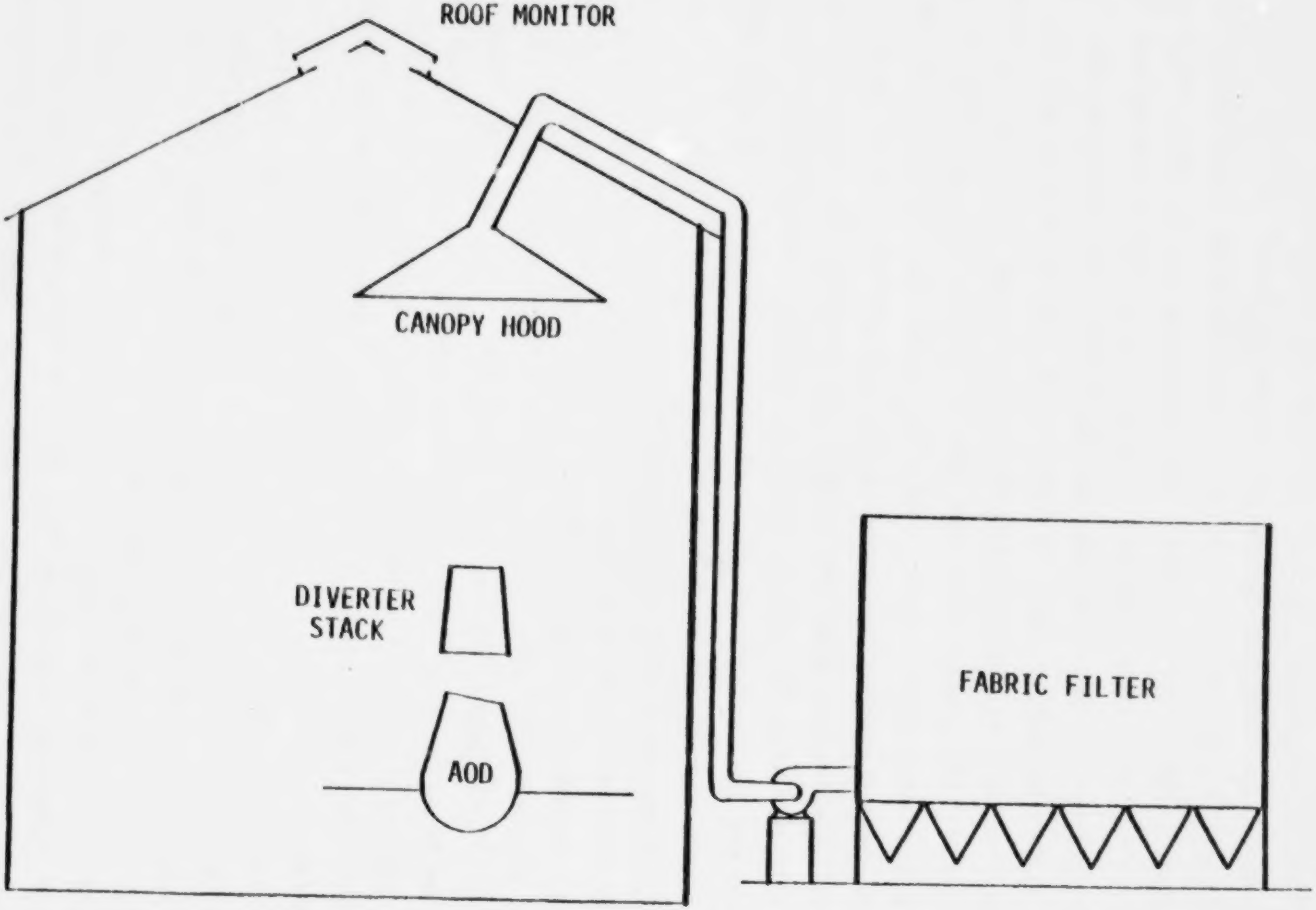

ROOF MONITOR
CANOPY HOOD
DIVERTER STACK
AOD
FABRIC FILTER

Figure 4-6. Diverter stack with canopy hood.

distance from the vessel mouth to the diverter stack or from the diverter stack to the canopy hood is great. Emissions that miss the canopy hood can be captured by a closed roof and scavenger duct system, if utilized; otherwise, these emissions will drift out of the shop through openings in the roof and walls.

4.3.2 Close-Fitting Hood With Canopy Hood

Another emission capture system for AOD vessels involves a close-fitting hood for process emissions and a canopy hood for fugitive emissions (Figure 4-7). The close-fitting hood, which may be moved away for charging and tapping, is typically situated 0.3 to 0.6 m (1 to 2 ft) above the top of the vessel when the vessel is in an upright position. The refining emissions are captured by the close-fitting hood, and any fugitive emissions are captured by the canopy hood. This system overcomes the problem of deflection of fumes during the steel refining operation by the overhead crane or by cross-drafts in the shop. Most new AOD installations are expected to use the close-fitting hood system because it achieves efficient fume capture with generally lower air flow volumes and better emissions capture than a diverter stack-canopy hood system.[17] The close-fitting hood requires more maintenance than the diverter stack system because of the very high temperature of the exhaust gases.

4.4 FUGITIVE EMISSIONS CAPTURE SYSTEM COMBINATIONS

Individual fugitive emissions capture technologies have been discussed in the previous sections. These technologies are seldom used alone and are typically used in combination with one or more technologies. This section presents those combinations of capture technologies that would be suitable for use industry wide. The fugitive emissions capture efficiency achievable by each combination is also presented. All of the fugitive emission capture system combinations have not been observed in operation. However, it is the engineering judgment of EPA that there is no technological reason that these capture combinations could not be used.

Table 4-1 presents six combinations of fugitive emissions capture technologies suitable for use on EAF's. The ranges of capture efficiencies (emission reductions) are based on observations of the operation of

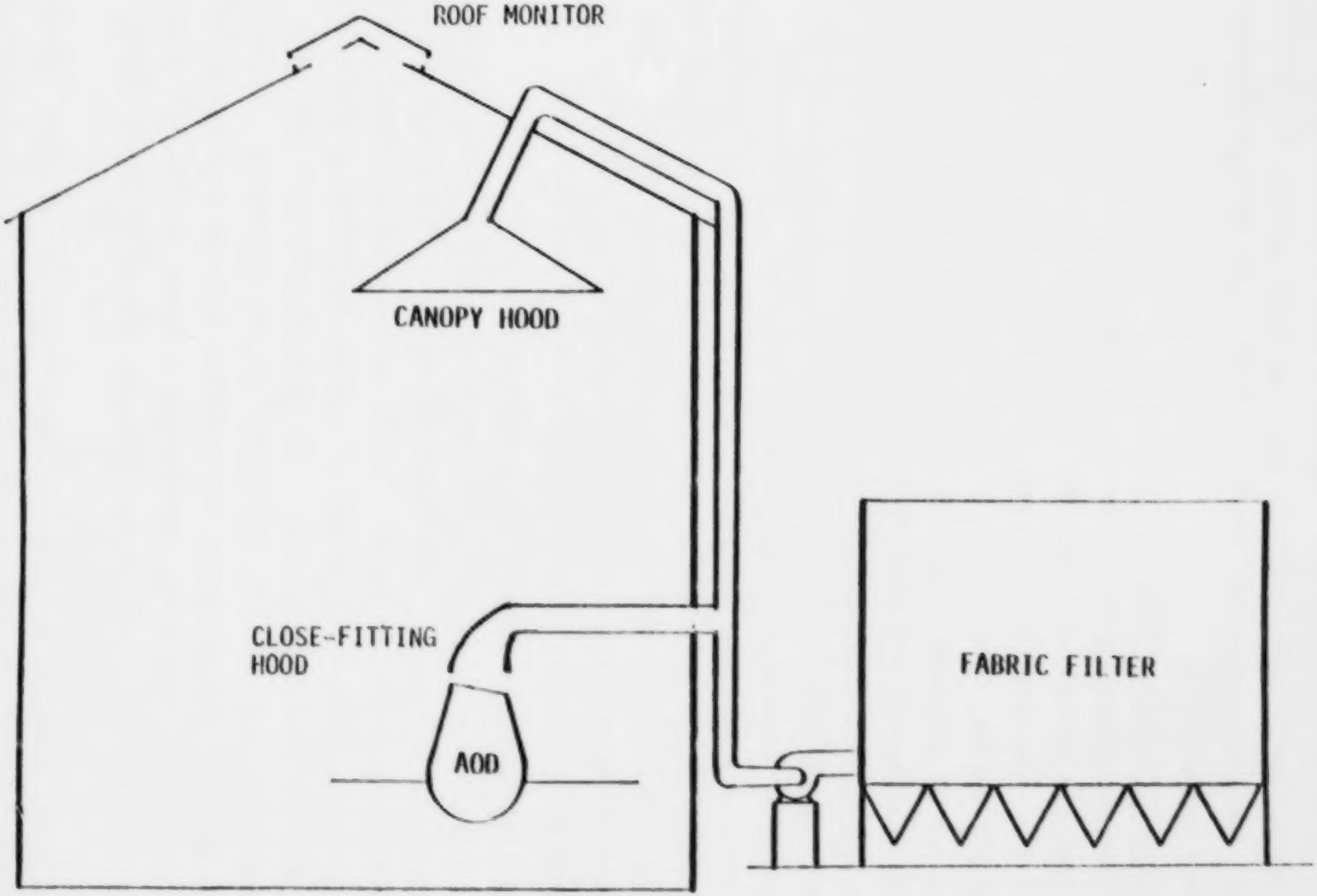

ROOF MONITOR
CANOPY HOOD
CLOSE-FITTING
HOOD
AOD
FABRIC FILTER

Figure 4-7. Close-fitting hood with canopy hood.

TABLE 4-1. FUGITIVE EMISSIONS CAPTURE TECHNOLOGY COMBINATIONS (CARBON AND SPECIALTY STEEL EAF)

Fugutive emission capture system combination	Capture equipment[a]	Estimated fugitive emission reduction,[b] percent
1	Single canopy hood, open roof monitor.	75-85
2	Segmented canopy hood, closed roof (over furnace)/open roof monitor elsewhere.	85-95
3	Single canopy hood, local tapping hood, local slagging hood, closed roof (over furnace)/ open roof monitor elsewhere.	85-95
4	Segmented canopy hood, scavenger duct, cross-draft partitions, closed roof (over furnace)/open roof monitor elsewhere.	90-95
5	Single canopy hood, total furnace enclosure, closed roof (over furnace)/open roof monitor elsewhere.	90-95
6	Segmented canopy hood, scavenger duct, cross-draft partitions, closed roof.	95-100

[a] DEC system used for process emissions capture on all alternatives.
[b] Estimate based on observation of technologies and engineering judgment.

individual technologies at various plants and on engineering studies and judgment as to the effectiveness of these technologies when used in combination.[14,18] Limited data are available to substantiate these capture efficiency estimates due to the difficulties involved in performing tests on the systems. Some plume photographic scaling techniques have been performed to help determine the hood efficiencies and help in the design of fume collection equipment.[18,19] Visible emission tests have been performed that demonstrate 100 percent fugitive emission reduction for some of the systems since there were no visible emissions observed coming from melt shop roof.[20,21] Table 4-2 presents four combinations of fugitive emissions capture technologies suitable for use on AOD vessels.

4.5 EXHAUST GAS CLEANING DEVICES

Following the capture and evacuation of the melt shop emissions, a control device is used to clean the dust-laden gas stream before the gases are vented to the atmosphere. The control device used in most U.S. steel mills with EAF's and AOD vessels is the fabric filter. Only one electrostatic precipitator (ESP) installation was found in use at an older EAF shop (the ESP's were installed in 1958). Less than 2 percent of the existing EAF units and no AOD units are known to use wet scrubbers. The predominate use of fabric filters is expected to continue; ESP's and scrubbers are expected to have only limited application. No process parameters or conditions are known to exist that preclude the use of a fabric filter on either an EAF or an AOD or that require the use of an ESP or scrubber.

Fabric filters have many advantages that make them suitable for control of EAF and AOD vessel emissions. Fabric filters use less energy than either scrubbers or ESP's for equivalent outlet particulate concentrations, are efficient collectors of very fine emissions, are tolerant of fluctuations in the inlet particle size distribution (which affects ESP's), and collect emissions in a dry form. The dust from the baghouse, which is easier to handle and recycle than the wastewater and sludge from scrubbers, can be wetted in a pug mill or pelletized before it is recyled or landfilled.

TABLE 4-2. FUGITIVE EMISSIONS CAPTURE TECHNOLOGY COMBINATIONS (SPECIALTY STEEL AOD)

Fugitive emission capture system combination	Capture equipment[a]	Estimated fugitive emission reduction,[b] percent
1	Single canopy hood, open roof monitor.	75-85
2	Single canopy hood, closed roof (over vessel)/open roof monitor.	85-95
3	Single canopy hood, scavenger duct, cross-draft partitions, closed roof (over vessel)/open roof monitor.	90-95
4	Single canopy hood, scavenger duct, cross-draft partitions, closed roof.	95-100

[a] Close-fitting hoods are used for process emissions capture on all combinations.

[b] Estimate based on observation of technologies and engineering judgment.

A fabric filter system (baghouse) consists of a number of filtering elements (bags) along with a bag cleaning system contained in a main shell structure with dust hoppers. Particulate-laden gases are passed through the bags so that the particles are retained on the fabric, thus cleaning the gas. Typically, a baghouse is divided into several compartments or sections. In larger installations, an extra section is often provided to allow one compartment to be out of service for cleaning at any given time without affecting the overall efficiency of the fabric filter.

The basic mechanisms available for cleaning particulate-laden gases are inertial impaction, diffusion, direct interception, and sieving. The first three mechanisms prevail only briefly during the first few minutes of cleaning with new or recently cleaned bags, while the sieving action of the dust layer accumulating on the fabric surface soon predominates. The sieving mechanism leads to high efficiency collection of particulates unless defects such as pinhole leaks in the bags or cracks in the filter cake appear.

In fabric filtration, both the collection efficiency and the pressure drop across the bag surface increase as the dust layer on the bag builds up. Since the system cannot continue to operate efficiently with an increasing pressure drop, the bags are cleaned periodically by reverse air flow, pulse-jet, or a shaker mechanism. Reverse air flow is typically used on fabric filter units controlling EAF and AOD vessel emissions. The air is forced through the bags being cleaned, causing them to collapse and the dust cake to fall into the hoppers below. Pulse-jet cleaning is used at a few EAF and AOD vessel installations. A sharp pulse of compressed air released into the bag causes a shock wave and reverses the air flow in the bag. The pulse of air deforms the bag and dislodges the dust cake into the hoppers below. The shaker mechanism physically shakes the bags to be cleaned, causing the dust cake to fall into the hoppers below.

The design of a fabric filter requires that certain information be known about the gas stream to be cleaned. The information usually needed is mass emission rate, volumetric flow rate, and particle characteristics. However, once initial experience has been gained with the performance of fabric filters in a particular industry (as it has with EAF's and AOD vessels in the steel industry), control device vendors can predict the range within which the key design parameters (e.g., the air-to-cloth [A/C] ratio, pressure drop, cleaning mechanism and frequency, and bag construction [e.g., material, weave]) must be maintained to achieve desired outlet emission concentrations. Baghouse design in the steel industry no longer requires specification of site-specific gas characteristics except the gas volume to be cleaned. Historical performance and the experience gained in the industray dictate that, in most cases, the A/C ratio will be around 3:1, the pressure drop across the bags will be between 7.6 and 12.7 cm (3 and 5 in.) water column (w.c.), the cleaning mechanism will be reverse air, and the bags will be constructed of a Dacron® polyester blend. After installation of the unit, the cleaning frequency is adjusted to optimize operation of the fabric filter. Pressure drop sensors or timers are used to initiate sequential compartment cleaning automatically on a preset time schedule.

The two types of fabric filters used in the industry are the positive-pressure type and the negative-pressure type. Pressurized fabric filter systems are those in which the effluent gases are forced through the fabric filter by a fan placed between the emission collection system and the fabric filter. The compartments in the positive-pressure fabric filter do not need to be airtight since only the dirty air side of the collector needs to be sealed.[1] Bag inspections and maintenance are easier to perform than on negative-pressure fabric filters, and the compartments can be entered while the positive-pressure fabric filter is in operation if the temperature is low enough for worker safety. Dirty air entering the fabric filter is filtered through the cloth and then vented to the atmosphere through louvers, stub stacks, or a ridge vent (monitor) on the top of the positive-pressure fabric filter.

The alternative to the pressurized system is a negative-pressure or suction-type fabric filter. The fan is placed on the clean air side of the fabric filter, and the effluent gas is drawn through the fabric. With this type of system, the bags must be kept airtight, and thus each compartment must be taken off-line for bag maintenance and replacement. Negative-pressure filters usually require less fan maintenance and less operating horsepower than the pressure type.[1] However, negative-pressure fabric filters may require more ductwork due to the need for a stack, may be more expensive because they must be built to withstand the suction created by the fans, and must be well sealed to prevent the introduction of dilution air.

Suction-type fabric filters are typically vented to the atmosphere through a common stack, which can easily be sampled for particulate emissions. Pressurized fabric filters usually do not have a stack; thus, testing these fabric filter systems for compliance with State and Federal regulations is difficult. Since use of the pressurized fabric filter system predominates on EAF and AOD units in the steel industry, a potential enforcement problem exists. A common method for testing these systems for particulate emissions has been the use of ambient high volume (hi-vol) samplers placed in each of the compartments. These hi-vol samplers are placed on the clean-air side of the bags so as to obtain representative samples of the exhaust gas. Because of the questionable accuracy of the results obtained, EPA does not recommend the use of hi-vol sampling procedures on future pressurized fabric filter emission tests (this recommendation does not affect previous agreements between governmental agencies and the steel companies). Two of the causes of the inaccuracies are the high bias of the gas volume sampled, which results in a low bias to the results, and the practice of turning the samplers upside down, which can result in particulate matter being lost when the sampler is turned off and handled. EPA prefers a Reference Method 5 sampling train with the probe inserted into the compartment of a pressurized fabric filter between the bags and the monovent, or in the monovent (ridgevent). Emission testing is discussed further in Appendix D.

Problems have also been recognized when performing continuous opacity monitoring on pressurized fabric filters. Some of these problems include an excessive path length in some applications, stratification of the gas flow, and the inherent difficulties involved when converting the opacities obtained to an equivalent stack diameter or to EPA Reference Method 9. These problems are also discussed in Appendix D.

4.6 EMISSION SOURCE TEST DATA

This section presents data obtained by EPA on the capture and control of particulate matter emissions from EAF and AOD fabric filter systems. The data are from field tests performed by EPA contractors or from performance tests submitted by industry or State agencies. Data are also presented on visible emissions obtained for fabric filter systems, shop roof monitors, and dust-handling equipment.

These data indicate that properly designed and operated fabric filters can achieve emission concentrations of 6 mg/dscm (0.0026 gr/dscf)* or less when operated on EAF, AOD, or combined EAF/AOD units. These same fabric filter units can achieve exhaust gas opacities of less than 3 percent when operated on EAF, AOD, or combined EAF/AOD units. Emissions from the shop roof monitors can be maintained below 6 percent opacity. The dust-handling equipment (i.e., that equipment from the baghouse dust hopper to and including the transfer equipment to the truck that hauls the dust) can be designed to exhibit less than 10 percent opacity.

4.6.1 Carbon Steel Shops

Source test data were obtained from 15 carbon steel shop fabric filter systems. Table 4-3 presents a summary of data from the plants tested. The tested plants represent the range of facilities expected to be regulated by any new NSPS with regard to EAF size, ducting configuration, capture equipment, scrap type, and level of furnace power.

Figure 4-8 presents the results of measurements of particulate concentrations at eight plants: A, B, C, D, E, F, G, and H. Each data point represents a separate sample collected by Reference Method 5. The maximum value for an average of three test runs was 6 mg/dscm (0.0026 gr/dscf) at Plants B and G. Data for Plants B, C, D, E, F, and G were obtained during NSPS compliance tests. Data from Plants A and H were obtained during an EPA source test and from a State compliance test, respectively. Data from the plants noted on Figure 4-8 have been determined to be suitable for setting and supporting an emission limit for EAF fabric filters. A detailed summary of these test results is presented in Appendix C.

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*mg/dscm = milligrams per dry standard cubic meter.
gr/dscf = grains per dry standard cubic foot.

TABLE 4-3. SUMMARY OF CARBON STEEL PLANT DATA

Plant	Reference	Furnace size[a]		No. furnaces ducted to tested fabric filter	Capture equipment[b]	Type scrap[c]
		Mg	(tons)			
A	22, 23	45.4, 68.0	(50, 75)	2	BE, CR	Unknown
B	24-26	36.3, 22.7	(40, 25)	2	SDH, CH, CR	Dirty
C	6, 27	49.9	(55)	1	TFE, CH, TH, CR	Dirty
D	11, 28	108.8 UHP[d]	(120)	1	CH, DEC, CR	Clean
E	29	117.9	(130)	1	CH, DEC, CR/OR	Unknown
F	30	45.4	(50)	3	CH, SDH, CR	Unknown
G	31	108.9	(120)	1	CH, DEC, CR	Unknown
H	32, 33	90.7	(100)	2	CH. DEC, OR	Dirty
I[e]	33	108.9	(120)	2	CH, DEC, CR	Unknwon
J	34, 35	317.5 UHP[d]	(350)	2	CH, DEC, TH, SH, CR/OR	Dirty
K	20	117.9	(130)	1	SCH, SDH, SD, CR	Unknown
L	36, 37	90.7	(100)	3	SCH, DEC, CR	Dirty
M	12, 38	204.1	(225)	2	SCH, DEC, CR/OR	Dirty
N	39, 40	104.3, 136 UHP	(115, 150)	1	CH, DEC, CDP, SD, CR/OR	Dirty
O	41, 42	90.7	(100)	2	SCH, DEC, LR	Dirty

[a] Normal power unless noted.

[b]
BE = building evacuation
CR = closed roof
TH = tapping hood
SH = slagging hood
CH = single canopy hood
TFE = total furnace enclosure
SCH = segmented canopy hood
SDH = side draft hood
DEC = direct shell evacuation control
LR = louvered roof monitor
SD = scavenger duct
CDP = cross-draft partitions
CR/OR = closed roof (over furnace)/open roof (elsewhere)

[c] Type of scrap is relative. Clean scrap has low proportion of oil and rust and is usually used in shops making higher quality grades of steel. Facilities making common grades of steel (e.g., reinforcing bars, structural shapes) will use any type of scrap, although most plants tend to avoid very oily scrap.

[d] UHP = ultra high power

[e] Only the DEC fabric filter was tested.

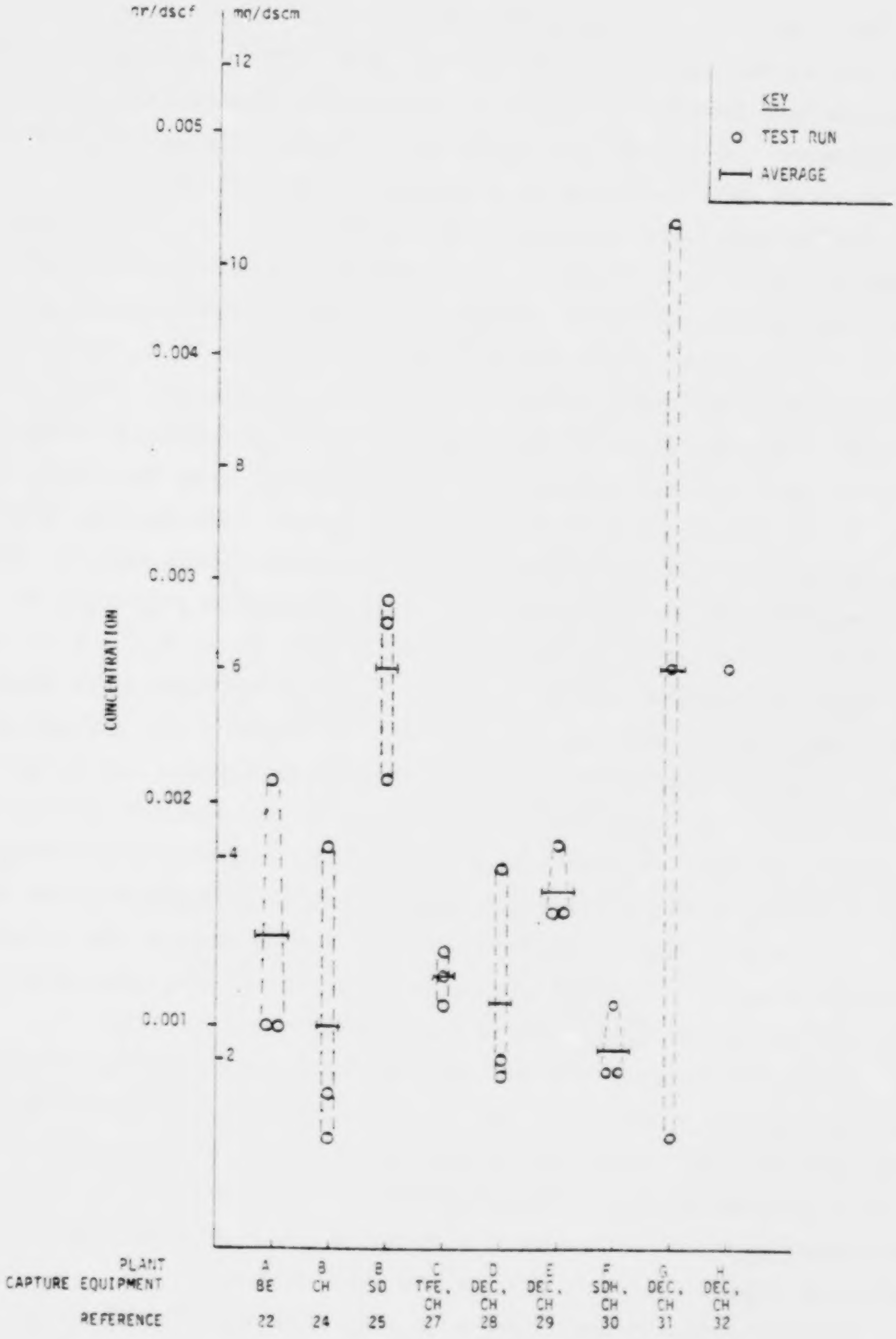

Figure 4-8. Summary of Particulate Matter Source Data for Carbon Steel EAF Fabric Filters (Reference Method 5).

Other data are available from tests at six carbon steel plants where the hi-vol sampling technique was used. These data will not be presented here because the results obtained are biased, and the EPA does not recommend the use of this technique. Further discussion on the weaknesses of this technique is presented in Appendix D.

Opacity data were obtained from the fabric filter exhaust gas stream at Plants B, C, F, G, H, I, J, and K with Reference Method 9 and continuous opacity monitors. Plants B, C, and F have negative-pressure fabric filters with stacks, while Plants G, H, I, J, K, L, M, and O have positive-pressure fabric filters with monovent exhausts. Plant N has a positive-pressure fabric filter with a monovent exhaust and a negative-pressure fabric filter with a stack. The opacity data for Plants B, C, F, G, H, I, J, and K are presented in Table 4-4. The maximum opacity observed by EPA Reference Method 9 was 0 percent. These opacity data were obtained concurrently with the particulate data presented in Figure 4-8. The fabric filters at Plants B, C, F, G, H, I, J, K, and the negative-pressure fabric filter at Plant N represent best demonstrated technology, (BDT); however, the test data at Plant N are not yet available. Plants L, M, O, and N were visited primarily to discuss the worker heat stress problem at steel facilities located in the Southern United States. The fabric filters at Plants L, M, and O and the positive-pressure fabric filter at Plant N are not considered BDT because of plant age, level of emission limit required, degree of maintenance, and design considerations.[43] Although some visible emission data were obtained, they are not being reported here nor used in the data base.

Table 4-5 presents visible emission data obtained from the shop roof monitors at Plants C, G, H, I, J, K, and N. Emissions from the shop roof monitors taken during periods of normal EAF operation were below 6 percent opacity. The roof monitors at Plants C, G, H, I, and K are closed over the entire melt shop while the roof monitors at Plant J and N are closed over the furnace and open elsewhere.

Visible emission data have also been obtained from the shop roof monitors at Plants B, L, M, and O. The overall emissions capture technology at these plants do not represent BDT, and the data obtained are not used

TABLE 4-4. SUMMARY OF VISIBLE EMISSION DATA FROM FABRIC FILTERS ON EAF'S AT CARBON STEEL SHOPS[15,25,27,29-34,44]

Plant	Length of observations, minutes	Maximum 6-minute average, percent
B[a,b]	960	2.5[c]
C[b,d]	36	0
C[b,d]	560	0
F[b]	18	0
G[a,e]	936	2.8[c]
H[e]	120	0
I[e]	60	0
J[e,f]	577	0[f]
K[e]	300	0

[a] From continuous monitor; not Reference Method 9.

[b] Single stack exhaust.

[c] Not 6-minute average; highest average from continuous monitor during a Method 5 test.

[d] Two separate tests at Plant C.

[e] Monovent exhaust.

[f] Reference Method 22.

TABLE 4-5. SUMMARY OF OPACITY DATA FROM SHOP ROOF MONITORS ON CARBON STEEL EAF SHOPS[15,20,27,31-33,44,45]

Plant	Furnace/ vessel	Furnace process	No. of 6-minute averages	Maximum 6-minute average opacity, percent	Average of 6-minute averages, percent
C[a] (NSPS)	EAF	Charge	5	1.3	0.5
		Melt	33	2.7	0.1
		Tap	6	0.4	0.1
C[a,b] (NSPS)	EAF	Heat cycle	88	5.0	0.25
G[c] (NSPS)	EAF	Charge Melt Tap	46	0	0
H[d]	EAF	Charge	10	12	5.0
		Melt	95	0	0
		Tap	5	33	23.0
I[c]	EAF	Heat cycle	10	0	0
J[e] (NSPS)	EAF	Charge	15	4.4	1.0
		Melt	106	4.2	0.2
		Tap	10	5.0	0.6
K[f] (NSPS)	EAF	Charge	5	0	0
		Melt	90	0	0
		Tap	5	0	0
N[g] (NSPS)	EAF	Charge	30	3.3	0.7
		Melt	94	3.1	0.1
		Tap	14	1.0	0.1

[a] Utilizes total furnace enclosure, canopy hood, closed roof.

[b] Second test at Plant C.

[c] Utilizes canopy hood, DEC system, and closed roof.

[d] Utilizes canopy hood, DEC system, and open roof monitor.

[e] Utilizes segmented canopy hood, DEC system, local tapping hood, closed roof over furnace/open roof monitor elsewhere.

[f] Utilizes segmented canopy hood, side draft hood, scavenger, closed roof.

[g] Utilizes canopy hood, DEC system, scavenger ducts with cross-draft partitions, closed roof over furnace/open elsewhere.

in the data base. The shop walls at Plant B do not extend to ground level. This creates cross-draft problems, which adversely impact on capture device efficiencies by causing high shop monitor opacities. As noted above, Plants L, M, and O were not visited as examples of BDT.

4.6.2 Specialty Steel Shops

Source test data were obtained from eight specialty steel shop fabric filter systems. Table 4-6 presents a summary of data relating to the plants tested. These data include fabric filter units handling EAF dust alone, AOD dust alone, and EAF and AOD dust combined. The tested plants represent the range of facilities that may be regulated by any new NSPS with regard to furnace/vessel size, ducting configuration, and capture equipment. Scrap type, a factor when evaluating emissions from carbon steel shops, is not a factor with specialty steel shops because of their almost exclusive use of clean scrap.

Figure 4-9 presents the results of measurements of particulate concentrations at Plants P, Q, and R. Each data point represents a separate sample collected by EPA Method 5. The maximum value for an average of three test runs was 3.5 mg/dscm (0.0015 gr/dscf) at Plant P.

Data from Plant P and the first test at Plant Q, shown in Figure 4-9, were obtained by EPA during the emission test program. Because the emission test reports are incomplete or contain discrepancies, the remainder of the data in Figure 4-9 are presented as supplementary information. Testing was performed with hi-vol samplers at six facilities to determine compliance with State regulations. These data will not be presented because the hi-vol technique provides biased results and the technique is not recommended by the EPA.

Opacity readings were obtained by EPA personnel from the fabric filter exhaust gas stream at Plants P, Q, and S. All of these units have monovent exhausts except Plant Q, which has stub stacks. These data are presented in Table 4-7. As with the carbon steel shop data, the maximum opacity observed by Reference Method 9 was zero percent.

Table 4-8 presents visible emission data obtained from the shop roof monitors at Plants Q and S. Emissions from the shop roof monitors were below 5 percent opacity. Both shops have closed roof monitors over the furnace/vessel area.

TABLE 4-6. SUMMARY OF SPECIALTY STEEL PLANT DATA

Plant	Reference	Furnace/vessel type and size, Mg (tons)	No. furnaces/ vessels ducted to tested fabric filter	Capture equipment[a]
P	46-48	EAF: 29.0 (32)	2	SCH, CR
		AOD: 29.0 (32)	2	SCH, CR
Q	13, 21, 49, 50	AOD: 18.1 (20)	1	SCH, SD, CR
Q	51	AOD: 18.1 (20)	1	SCH, SD, CR
R	51	EAF: 38.1 (42)	2	CH, CR
		AOD: 45.4 (50)	1	CFH, CH, CR
S	52-54	EAF: 45.4 (50)	1	CH, CR
		AOD: 45.4 (50)	1	CFH, CH, CR

[a] CFH = close-fitting hood
CH = single canopy hood
CR = closed roof
SCH = segmented canopy hood
SD = scavenger duct

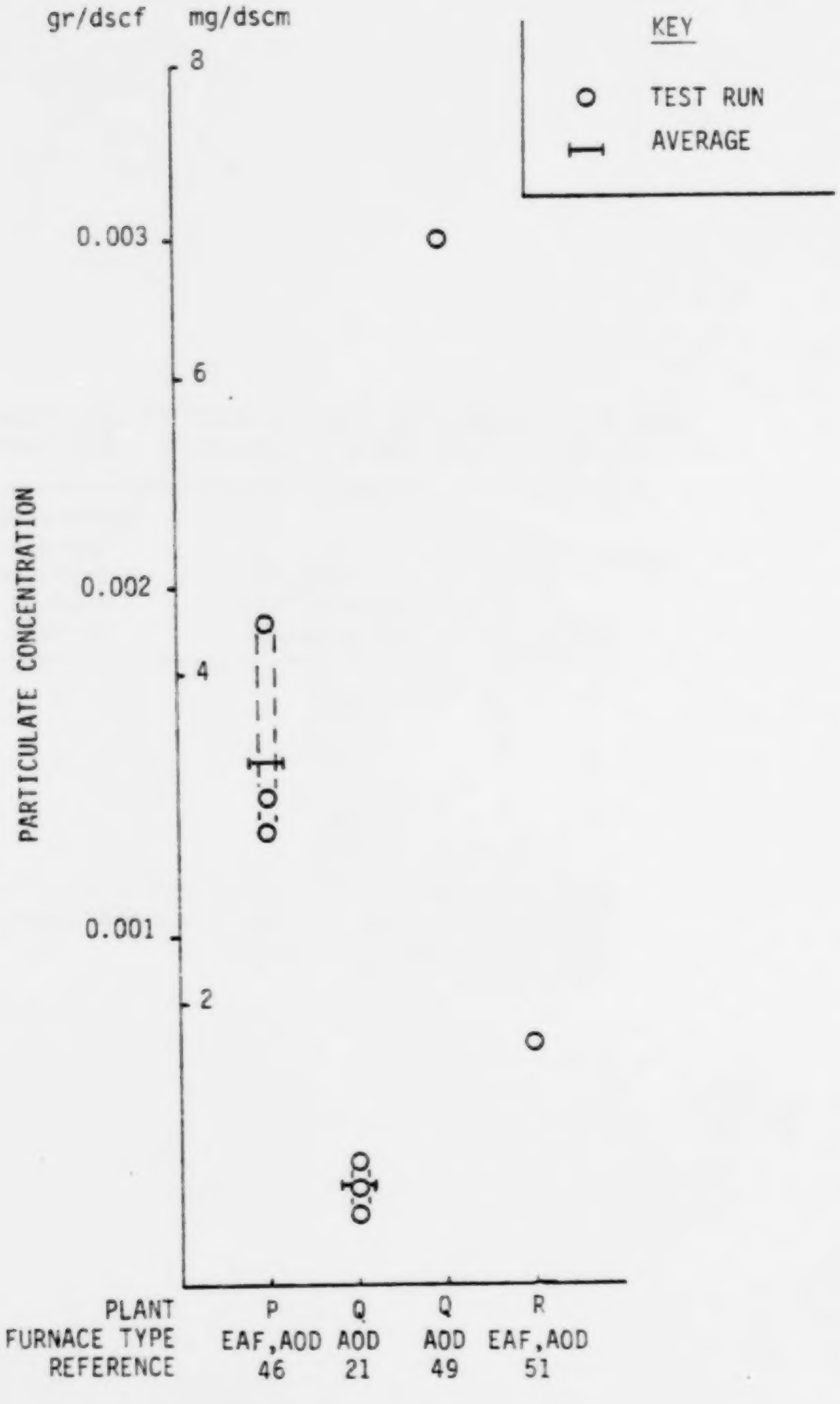

Figure 4-9. Summary of particulate matter source data for specialty steel shop fabric filters (Reference Method 5).

TABLE 4-7. SUMMARY OF VISIBLE EMISSION DATA FROM FABRIC FILTERS ON EAF'S AND AOD'S AT SPECIALTY STEEL SHOPS[21,46,52]

Plant	Length of observations in minutes	Maximum VE's based on 6-minute average, percent
P	438[a]	0
Q	408[b]	0
S	336[c]	0
	318[b]	0

[a] One fabric filter for EAF's and AOD vessels.
[b] AOD vessel fabric filter.
[c] EAF fabric filter.

TABLE 4-8. SUMMARY OF VISIBLE EMISSION DATA FROM SHOP ROOF MONITORS ON SPECIALTY STEEL SHOPS[21,52]

Plant	Furnace/ vessel	Furnace process	No. of 6-minute averages	Maximum VE's based on 6-minute averages, percent	Average of 6-minute averages, percent
Q[a]	AOD	Heat cycle	69	0	0
S[b]	EAF and AOD	Heat cycle	55	5	0.1

[a] Utilizes canopy hood, scavenger duct, closed roof.
[b] Utilizes close-fitting hood, canopy hood, closed roof.

Plant P is an older shop and, while nominally a closed shop, has numerous open seams between sheet metal sections on the walls and does not represent BDT. Visible emissions were seen exiting the building from these open seams. The data obtained for the shop monitor emissions at Plant P are not reported here and are not included in the data base.

4.6.3 Dust-Handling Equipment

Table 4-9 presents visible emission data obtained from the dust-handling equipment at Plants B, C, P, and Q. The data for Plants B and C were obtained using Reference Method 9 and show a maximum 6-minute average opacity of 0.6 and 5.0 percent, respectively. Some of the data for Plant Q were obtained with Reference Method 9 and show a maximum 6-minute average opacity of 7.3 percent. The data for Plant P and some data for Plant Q were obtained using Reference Method 22, and no visible emissions were observed during a total of 654 minutes of observation at these two facilities. All of these plants use an enclosed system of dust collection.

4.6.4 Fluorides and Trace Elements in Particulate Emissions

The fabric filter exhaust gas particulate and fabric filter dust catch at Plants P and Q were analyzed for fluorides, chromium, lead, and nickel. These limited results are presented in Table 4-10. Emissions to the atmosphere of these compounds do not appear to be significant, with maximum emissions being only 495 kg/yr (1,090 lb/yr) of flouride. The other compounds analyzed are emitted in significantly lower quantities.

TABLE 4-9. SUMMARY OF VISIBLE EMISSION DATA FROM DUST-HANDLING SYSTEMS AT EAF AND AOD VESSEL STEEL MILL FACILITIES[21,24,46,55]

Plant	Length of observations in minutes	Maximum 6-minute average, percent
B[a]	12	0.6
C[a]	20	5.0
P[b]	594	0[c]
Q[d]	60	0[c]
Q[d]	48	7.3[e]

[a] EAF fabric filter.

[b] EAF/AOD fabric filter.

[c] EPA Method 22 (no emissions were visible). The operation observed did not include the dust transfer from the storage silo to truck.

[d] AOD fabric filter.

[e] The operations observed included the dust transfer from the storage silo to truck.

TABLE 4-10. SUMMARY OF TRACE CONSTITUENT CONCENTRATIONS ANALYSIS, ppm (kg/yr, lb/yr)

Plant:	P[46]		Q[21]	
Constituent	Fabric filter exhaust gas[a]	Fabric filter catch	Fabric filter exhaust gas[b]	Fabric filter catch
Fluorides	31,600 (495, 1,090)	47,200	10,300 (15, 29)	15,200
Chromium	17,400[c] (277, 594)	39,200	7,600[c] (11, 21)	49,200
Lead	5,800[c] (94, 203)	8,400	<2,300[c,d] (<3, <8)	2,200
Nickel	7,600[c] (119, 267)	16,300	6,800[c] (7, 21)	21,500

[a] Assumes emission concentration and flow rate of tested plant and 4,950 operating hours per year.

[b] Assumes production of 37,420 Mg/yr (41,250 tons/yr).

[c] Average of two samples.

[d] Detection limit.

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5. MODIFICATION AND RECONSTRUCTION

New source performance standards (NSPS) apply to facilities whose construction, modification, or reconstruction commenced [as defined under 40 CFR 60.2(i)] after proposal of the standards. Such facilities are termed "affected facilities." Standards of performance are not applicable to "existing facilities," which, as defined under 40 CFR 60.2(aa), are facilities whose construction, modification, or reconstruction commenced on or before proposal of the standards. However, an existing facility may become an affected facility and therefore subject to standards if the facility undergoes modification or reconstruction.

Modification and reconstruction are defined under 40 CFR 60.14 and 60.15, respectively. The provisions of these sections are summarized in Section 5.1 below. Section 5.2 examines the applicability of these provisions to electric arc furnace and argon-oxygen decarburization vessel facilities and describes conditions under which existing facilities could become subject to standards of performance.

It is important to note that a stationary source may contain both affected and existing facilities and that reclassifying a facility from existing to affected status by modification or reconstruction does not subject any other facility within that source to the standards of performance.

5.1 SUMMARY OF MODIFICATION AND RECONSTRUCTION PROVISIONS

5.1.1 Modification

Section 40 CFR 60.14 defines modification as follows:

> Except as provided under paragraph (e) and (f) of this section, any physical or operational changes to an existing facility which result in an increase in emission rate to the atmosphere of any pollutant to which a standard applies shall be a modification. Upon modification, an existing facility shall become

> an affected facility for each pollutant to which a standard applies and for which there is an increase in the emission rate.

Paragraph (e) specifies certain physical or operational changes that are not considered modifications irrespective of any changes in the emission rate. These changes include:

1. Routine maintenance, repair, and replacement;

2. An increase in production rate accomplished without a capital expenditure [as defined in Section 60.2(bb)];

3. An increase in hours of operation;

4. Use of alternate fuels or raw materials if the existing facility were designed to accommodate the alternate fuel or raw material prior to the standard [conversion to coal required for energy considerations, as specified in Section 111 (a)(8) of the Clean Air Act, is also exempted];

5. Addition or use of any system or device whose primary function is the reduction of air pollutants, except when an emission control system is removed or replaced by a system considered to be less efficient; and

6. Relocation or change in ownership.

Paragraph (f) provides that, should conflicts in provisions arise, the provisions of each subpart supercede those of 40 CFR 60.14.

Paragraph (b) of CFR 60.14 clarifies what constitutes an increase in emissions and the methods for determining the increase. These methods include the use of emission factors, material balances, continuous monitoring systems, and manual emission tests. Paragraph (c) of 40 CFR 60.14 affirms that the addition of an affected facility to a stationary source does not make any other facility within the source subject to the standards of performance.

5.1.2 Reconstruction

Section 40 CFR 60.15 defines reconstruction as follows:

> An existing facility, upon reconstruction, becomes an affected facility, irrespective of any change in emission rate. "Reconstruction" means the replacement of components of an existing facility to such an extent that: (1) the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost that would be required to construct a comparable entirely new facility, and (2) it is technologically

> and economically feasible to meet the applicable standards set forth in this part.

The purpose of this provision is to ensure that an existing facility is not perpetuated by replacing all but a few components rather than totally replacing the facility in order to avoid becoming subject to applicable standards of performance.

5.2 APPLICABILITY TO ELECTRIC ARC FURNACES AND ARGON-OXYGEN DECARBURIZATION VESSELS IN THE STEEL INDUSTRY

The following components will be examined to decide whether an EAF has been modified or reconstructed:

1. Furnace shell, including roof;
2. Transformer; and
3. Emissions control system (capture devices, ductwork, control device).

The following components will be examined to decide whether an AOD vessel has been modified or reconstructed:

1. Vessel shell; and
2. Emission control system (capture devices, ductwork, control device).

Except as noted in Section 5.1.1, any physical or operational change to any of these items that would result in an increase in the particulate emission rate (emissions per hour) to the atmosphere could be considered a modification. Changes to an EAF that could increase emissions and be considered modifications include changes to the furnace shell (including the roof), an increase in transformer capacity, or changes to the emissions control system. Changes to an AOD vessel that could increase emissions include changes to the vessel shell or changes to the emissions control system.

Replacement of more than one item may be reconstruction, depending on the costs involved. The installation of water-cooled walls on an EAF, an increase in the transformer capacity to raise the melt rate, or the conversion of a normal-power EAF to ultra high power (UHP) may be reconstruction because the cumulative capital costs of the new components exceed 50 percent of the capital costs for a new facility.

The enforcement division of the appropriate EPA regional office should be contacted whenever a source has questions regarding modification and reconstruction.

6. MODEL PLANTS AND REGULATORY ALTERNATIVES

6.1 INTRODUCTION

Model plants are used as parametric descriptions of the general types of EAF's and AOD vessels that are expected to be constructed and modified/reconstructed within the industry in the future. Model plants are used because it is impractical to evaluate environmental, economic, and energy impacts of the various emission capture and control technologies for every possible plant configuration. In order that the analyses be representative of the industry as a whole, the model plants are designed to cover the range of possible plant arrangements and are not necessarily intended to represent any particular facility. The following sections of this chapter describe the model plants and the alternative methods of regulating the affected facilities.

6.2 MODEL PLANTS

Nine model plants have been developed to represent EAF's and AOD vessels in steel mills. Brief descriptions of the plants are presented in Table 6-1. Model plants 1 through 6 represent a range of new, modified, or retrofit EAF's in the carbon steel shops. Model plant 7 represents a likely retrofit EAF in either a carbon or specialty steel shop. Model plants 8 and 9 represent EAF's and AOD vessels in new specialty steel shops.

Six model furnace/vessel sizes have been selected to characterize the spectrum of EAF and AOD steel facilities. These furnaces include four EAF sizes (three normal-power, one UHP) and two AOD vessel sizes. The furnace sizes are based on the furnace design capacity rather than on the melting capacity in megagrams per hour (tons per hour) because of the variability in the grades of steel produced and the amount of refining

TABLE 6-1. MODEL PLANTS

Number	Plant description	Steel production Mg/yr	(tons/yr)
1[a]	A new shop with a 22.7-Mg (25-ton) EAF.	37,420	(41,250)
2[a]	A new shop with a 90.7-Mg (100-ton) EAF.	163,300	(180,000)
3[a]	A new shop with a 272.2-Mg (300-ton) EAF.	596,000	(657,000)
4[a]	A new shop with a 136.1-Mg (150-ton) UHP EAF.	434,800	(479,300)
5[a]	A modification of a 136.1-Mg (150-ton) normal power EAF to a UHP EAF.	434,800	(479,300)
6[a]	A retrofit of a 272.2-Mg (300-ton) EAF into an existing shop.	596,000	(657,000)
7[a,b]	A retrofit of a 22.7-Mg (25-ton) EAF into an existing shop.	37,420	(41,250)
8[b]	A new shop with a 22.7-Mg (25-ton) AOD vessel and a 22.7-Mg (25-ton) EAF.	37,420	(41,250)
9[b]	A new shop with a 90.7-Mg (100-ton) AOD vessel and a 90.7-Mg (100-ton) EAF.	163,300	(180,000)

[a] Carbon steel shop.
[b] Specialty steel shop.

done in the furnace, which affects the heat length and number of heats per day. The sizes of EAF's with normal power capacities are 22.7 Mg (25 tons), 90.7 Mg (100 tons), and 272.2 Mg (300 tons), representing small, medium, and large EAF's, respectively. The fourth EAF size, 136.1 Mg (150 tons), represents the UHP furnaces. The AOD vessel sizes are 22.7 Mg (25 tons) and 90.7 Mg (100 tons), representing the range of vessel sizes that are projected to be built.

The technical parameters are presented in Table 6-2 for EAF's in carbon steel shops and in Table 6-3 for EAF's and AOD vessels in specialty steel shops. The parameters are based on design and performance data obtained during the development of this document.[1]

Design and operating improvements have been made in the industry since the development of the existing standards of performance to achieve higher production rates. These improvements have led to certain differences between the parameters noted in Tables 6-2 and 6-3 and those used during the development of the existing standards of performance, particularly with regard to heat times. The average heat time for carbon steel, normal-power EAF's has decreased in the past 5 years, from 3.5 to 3 hours. The reasons for this decrease in heat times include: improved melting efficiency and operating practices; the use of improved refractories, water-cooled furnace walls and roofs, and higher current density, which allows more power input and faster melting; more refining performed outside the furnace; increased computerization for greater control of electrical input; faster and more accurate analysis and processing of metallurgical samples; and increased competition from foreign steel companies, which necessitates more economical production.[2,3] Compared to a normal-power EAF, the UHP furnace has an even shorter heat time (approximately 2 hours), which is facilitated by higher transformer capacities and the use of water-cooled furnace walls and roofs.

The average heat time for a specialty steel EAF shop has been reduced in the past 5 years from 7 to 3 hours. This reduction in heat time results primarily from the increased use of duplexing, which is the melting and refining of steel in separate vessels (the EAF functions primarily as a metal melter and another vessel is used to refine the molten metal). This method of operation is significantly different

TABLE 6-2. MODEL FURNACE PARAMETERS--CARBON STEEL[1]

Process information	Furnace ID			
	A	B	C	D
Furnace type	EAF	EAF	EAF	EAF
Furnace capacity, Mg/heat	22.7	90.7	272.2	136.1
tons/heat	25	100	300	150
Furnace transformer rating	Normal	Normal	Normal	UHP
Heat time, h	3	3	3	2
Production rate, Mg/day	136	544	1,633	1,225
tons/day	150	600	1,800	1,350
heats/day[a]	6	6	6	9
Operating time, h/day	24	24	24	24
days/yr	275	300	365	355
h/yr	6,600	7,200	8,760	8,520
Annual production, Mg x10^3	37.42	163.3	596.0	434.8
tons x10^3	41.25	180.0	657.0	479.3
Charge time, min	3-5	3-5	5-10	5-7
Backcharge time, min	3-5	3-5	5-10	5-7
Slag time, min	5	5	5	5
Tap time, min	5-7	5-7	7-10	6-8
Operating (tap) temperature				
°C	1620	1620	1620	1620
°F	2950	2950	2950	2950
Transformer capacity, kVA	10,600	42,500	127,500	75,000
Electricity use				
MJ/Mg of steel	1,985	1,985	1,985	1,985
kWh/ton of steel	500	500	500	500
Shop monitor height, m	27.4	33.5	38.1	36.6
ft	90	110	125	120
Uncontrolled emissions				
kg/h	114	454	1,361	1,020
lb/h	250	1,000	3,000	2,250
kg/Mg	15	15	15	15
lb/ton	30	30	30	30
Mg/yr[b]	561.3	2,499.4	6,940.5	6,522.3
tons/yr[b]	618.8	2,700.0	9,855.0	7,189.5

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[a] The daily production averages about six heats (furnaces A, B, and C) and nine heats (furnace D) because of process delays, refractory gunning, and furnace maintenance that is performed between heats.

[b] The annual emissions are calculated by multiplying the annual production by the emission rate.

TABLE 6-3. MODEL FURNACE PARAMETERS--SPECIALTY STEEL[1]

Process information	Furnace/vessel ID			
	A	B	E	F
Furnace type	EAF	EAF	AOD	AOD
Furnace capacity, Mg/heat	22.7	90.7	22.7	90.7
tons/heat	25	100	25	100
Furnace transformer rating	Normal	Normal	--	--
Heat time, h	3	3	1.5	1.5
Production rate, Mg/day	136	544	136	544
tons/day	150	600	150	600
heats/day[a]	6	6	6	6
Operating time, h/day	24	24	24	24
days/yr	275	300	275	300
h/yr	6,600	7,200	6,600	7,200
Annual production, Mg x10^3	37.42	163.3	37.42	163.3
tons x10^3	41.25	180.0	41.25	180.0
Charge time, min	3-5	3-5	3	3
Backcharge time, min	3-5	3-5	--	--
Slag time, min	5	5	3	3
Tap time, min	5-7	5-7	5	5
Operating (tap) temperature				
°C	1620	1620	1620	1620
°F	2950	2950	2950	2950
Transformer capacity, kVA	10,600	42,500	--	--
Electricity use				
MJ/Mg of steel	1,985	1,985	--	--
kWh/ton of steel	500	500	--	--
Shop monitor height, m	27.4	33.5	27.4	33.5
ft	90	110	90	110
Uncontrolled emissions				
kg/h	114	454	121	484
lb/h	250	1,000	267	1,067
kg/Mg	15	15	8	8
lb/ton	30	30	16	16
Mg/yr[b]	561.3	2,499.9	299.3	1,306.4
tons/yr[b]	618.8	2,700.0	330.0	1,440.0

[a] Furnaces A and B have an average production of six heats per day. Vessels E and F refine the molten steel that was melted in Furnaces A and B, respectively. Therefore, even though the heat time for vessels is half that of the furnaces, they also average six heats a day.

[b] The annual emissions are calculated by multiplying the annual production by the emission rate.

because in the past EAF's were used for both melting and refining in specialty steel shops. Industry sources indicate that most specialty steel shops that are to be built will have a duplexing system, with EAF's used to melt the scrap and do minimal refining.[4-7]

The nature of the gas stream from EAF's and AOD vessels is such that most of the associated ductwork and gas cleaning devices can be constructed of carbon steel. The direct fume extraction equipment, such as the DEC on the EAF and the close-fitting hood on the AOD vessel, are subject to very high temperatures and must either be lined with refractory material or ceramic fiber blankets or must be water-cooled to avoid excessive wear.[6] The diverter stack or close-fitting hood above the AOD vessel is typically made of stainless steel so that it can withstand the heat from the vessel. The exhaust gas characteristics, such as particle size and composition, are discussed in Chapter 3.

The existing combinations of capture technologies for the EAF's and AOD vessels are presented in the matrix in Table 6-4. Each capture configuration is presented as an example of the equipment that a model plant might utilize to meet one of the regulatory alternatives that is discussed later in this chapter. The capture technologies are based on those used in well-controlled shops that were observed during this study.

Table 6-5 shows the air flow rates per megagram (ton) of furnace/vessel capacity used to establish the flows shown in Tables 6-6 through 6-9. This information is based on that obtained from well-controlled shops.[1] The fabric filter information for the EAF's in carbon steel shops is presented in Tables 6-6 and 6-7 and for the EAF's and AOD vessels in specialty steel shops in Tables 6-8 and 6-9. The information presented for the fabric filters was based on worst-case conditions. In Tables 6-8 and 6-9, some of the flow rates were derived by combining the flow for an AOD vessel with the flow for an EAF. This was done to provide adequate flow for both units when they are in their most polluting mode of operation (i.e., EAF melting, AOD refining with high percentage of oxygen). These flow figures will be used for calculating costs in Chapter 8. Other, less conservative air flows might be possible when both the EAF and AOD vessel are ducted to the same fabric filter.

TABLE 6-4. MODEL PLANTS WITH CAPTURE CONFIGURATION OPTIONS

Model plant designation	Model plant No.	Capture configurations[a]						
		EAF: DEC, CH,OR	AOD: CFH, CH,OR	EAF: DEC,SCH, SD,CDP, (or CH, TH,SH), CR/OR	AOD: CFH,CH, CDP,SD, CR/OR	EAF: DEC,SCH, SD,CDP, (or CH, TH,SH), CR	AOD: CFH,CH, SD,CDP, CR	EAF: TFE,CH, TH,CR
Carbon Steel Shop								
25-ton EAF	1	x		x		x		x
100-ton EAF	2	x		x		x		
300-ton EAF	3	x		x		x		
150-ton UHP[b] EAF	4	x		x		x		
150-ton normal EAF modification to UHP EAF	5	x		x		x		
300-ton retrofit	6	x		x		x		
25-ton retrofit	7	x		x		x		x
Specialty Steel Shop								
25-ton EAF and AOD	8							
Ducted together		x	x	x	x	x	x	
Ducted separately		x	x	x	x	x	x	
100-ton EAF and AOD	9							
Ducted together		x	x	x	x	x	x	
Ducted separately		x	x	x	x	x	x	

[a] CDP = cross-draft partitions
CFH = close-fitting hood
CH = canopy hood
CR = closed roof
CR/OR = closed roof (over furnace)/open roof monitor (elsewhere)
DEC = direct-shell evacuation control
OR = open roof monitor
SCH = segmented canopy hood
SD = scavenger duct
SH = slagging hood
TFE = total furnace enclosure
TH = tapping hood

[b] UHP = ultra high power

TABLE 6-5. AIR FLOW RATES PER UNIT OF FURNACE/VESSEL CAPACITY[1]

Furnace type	Furnace ID (plant type)	Regulatory alternative[a]	Air flow[b] (m³/s)/Mg[c]	Air flow[b] acfm/ton[d]
EAF	A (carbon, specialty)	1, 2	2.00	3,850
EAF	A (carbon, specialty)	3	2.10	4,050
EAF	B (carbon, specialty)	1, 2	2.00	3,850
EAF	B (carbon, specialty)	3	2.10	4,050
EAF	C (carbon)	1, 2	0.80	1,550
EAF	C (carbon)	3	0.91	1,750
EAF	D (carbon)	1, 2	2.07	4,000
EAF	D (carbon)	3	2.18	4,200
AOD	E (specialty)	1, 2	2.43	4,700
AOD	E (specialty)	3	2.64	5,100
AOD	F (specialty)	1, 2	2.43	4,700
AOD	F (specialty)	3	2.64	5,100

[a] See Tables 6-10 and 6-11.
[b] At 121°C (250°F).
[c] $(m^3/s)/Mg$--cubic meters per second per megagram.
[d] acfm/ton--actual cubic feet per minute per ton.

TABLE 6-6. MODEL FURNACE PARAMETERS--CARBON STEEL FABRIC FILTER INFORMATION[1]
(Metric units)

Furnace type[a] Capture equipment[b] Regulatory alternative[c]	A 1 1	A 2 2	A 3 3	A 4 3	B 1 1	B 2 2	B 3 3
Air flow rate, m^3/s[d]							
Total	45.4	45.4	47.7	34.2	181.7	181.7	191.1
Canopy	31.3	28.9	28.9	16.5	125.1	115.6	115.6
DEC	14.1	14.1	14.1	--	56.6	56.6	56.6
TFE	--	--	--	17.7	--	--	--
Scavenger	--	2.4	4.7	--	--	9.5	18.9
Temperature, °C	121	121	121	121	121	121	121
No. compartments, total	8	8	7	12	20	20	17
No. bags, total	384	384	420	288	1,440	1,440	1,530
Bag type	Dacron® polyester						
Net air-to-cloth ratio[e]	3.18:1	3.18:1	3.13:1	3.05:1	3.13:1	3.13:1	3.13:1
Gross air-to-cloth ratio	2.79:1	2.79:1	2.68:1	2.80:1	2.97:1	2.97:1	2.94:1
No. fans	2	2	2	2	5	5	5
Fan wattage, each	96,980	96,980	104,440	85,190	171,580	171,580	171,580
Net cloth area,[e] m^2	2,826.0	2,826.0	3,010.0	2,210.3	11,437.8	11,437.8	12,039.8
Gross cloth area, m^2	3,210.6	3,210.6	3,511.6	2,411.2	12,039.8	12,039.8	12,792.3
Monitor height,[f] m	22.9	22.9	22.9	22.9	22.9	22.9	22.9
Moisture, percent	1	1	1	1	1	1	1
Pressure drop, cm	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7

Furnace type[a] Capture equipment[b] Regulatory alternative[c]	C 1 1	C 2 2	C 3 3	D 1 1	D 2 2	D 3 3
Air flow rate, m^3/s[d]						
Total	219.4	219.4	247.7	283.1	283.1	297.3
Canopy	186.5	172.3	186.5	192.5	178.3	178.4
DEC	32.9	32.9	32.9	90.6	90.6	90.6
TFE	--	--	--	--	--	--
Scavenger	--	14.2	28.3	--	14.2	28.3
Temperature, °C	121	121	121	121	121	121
No. compartments, total	24	24	15	23	23	23
No. bags, total	1,728	1,728	1,980	2,346	2,346	2,346
Bag type	Dacron® polyester					
Net air-to-cloth ratio[e]	3.12:1	3.12:1	3.16:1	3.02:1	3.02:1	3.12:1
Gross air-to-cloth ratio	2.99:1	2.99:1	2.95:1	2.84:1	2.87:1	2.98:1
No. fans	5	5	6	6	6	6
Fan wattage, each	179,040	179,040	179,040	179,040	179,040	186,500
Net cloth area,[e] m	13,845.8	13,845.8	15,451.1	18,461.1	18,461.1	18,762.1
Gross cloth area, m^2	14,447.8	14,447.8	16,554.8	19,614.9	19,614.9	19,614.9
Monitor height,[f] m	30.5	30.5	30.5	30.5	30.5	30.5
Moisture, percent	1	1	1	1	1	1
Pressure drop, cm	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7

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[a] From Table 6-2.

[b] 1 = DEC, canopy hood, open roof. 2 = DEC, segmented canopy hood, scavenger duct, cross-draft partitions, open/closed roof. 3 = DEC, segmented canopy hood, scavenger duct, cross-draft partitions, closed roof. 4 = TFE, canopy hood, closed roof.

[c] From Table 6-10.

[d] At temperature noted.

[e] One compartment off-line for cleaning.

[f] Fabric filter monitor height above grade.

TABLE 6-7. MODEL FURNACE PARAMETERS--CARBON STEEL FABRIC FILTER INFORMATION[1]
(English units)

Furnace type[a] Capture equipment[b] Regulatory alternative[c]	A 1 1	A 2 2	A 3 3	A 4 3	B 1 1	B 2 2	B 3 3
Air flow rate, acfm[d]							
Total	96,250	96,250	101,250	72,500	385,000	385,000	405,000
Canopy	66,250	61,250	61,250	35,000	265,000	245,000	245,000
DEC	30,000	30,000	30,000	--	120,000	120,000	120,000
TFE	--	--	--	37,500	--	--	--
Scavenger	--	5,000	10,000	--	--	20,000	40,000
Temperature, °F	250	250	250	250	250	250	250
No. compartments, total	8	8	7	12	20	20	17
No. bags, total	384	384	420	288	1,440	1,440	1,530
Bag type	------------------------------ Dacron® polyester ------------------------------						
Net air-to-cloth ratio[e]	3.18:1	3.18:1	3.13:1	3.05:1	3.13:1	3.13:1	3.13:1
Gross air-to-cloth ratio	2.79:1	2.79:1	2.68:1	2.80:1	2.97:1	2.97:1	2.94:1
No. fans	2	2	2	2	5	5	5
Fan horsepower, each	130	130	140	115	230	230	230
Net cloth area,[e] ft²	30,240	30,240	32,400	23,760	123,120	123,120	129,600
Gross cloth area, ft²	34,560	34,560	37,800	25,920	129,600	129,600	137,700
Monitor height,[f] ft	75	75	75	75	75	75	75
Moisture, percent	1	1	1	1	1	1	1
Pressure drop, in.	3-5	3-5	3-5	3-5	3-5	3-5	3-5

Furnace type[a] Capture equipment[b] Regulatory alternative[c]	C 1 1	C 2 2	C 3 3	D 1 1	D 2 2	D 3 3
Air flow rate, acfm[d]						
Total	465,000	465,000	525,000	600,000	600,000	630,000
Canopy	395,250	365,250	395,250	408,000	378,000	378,000
DEC	69,750	69,750	69,750	192,000	192,000	192,000
TFE	--	--	--	--	--	--
Scavenger	--	30,000	60,000	--	30,000	60,000
Temperature, °F	250	250	250	250	250	250
No. compartments, total	24	24	15	23	23	23
No. bags, total	1,728	1,728	1,980	2,346	2,346	2,346
Bag type	---------------------------- Dacron® polyester --------------------					
Net air-to-cloth ratio[e]	3.12:1	3.12:1	3.16:1	3.02:1	3.02:1	3.12:1
Gross air-to-cloth ratio	2.99:1	2.99:1	2.95:1	2.84:1	2.84:1	2.98:1
No. fans	5	5	6	6	6	6
Fan horsepower, each	240	240	240	240	240	250
Net cloth area,[e] ft	149,040	149,040	166,320	198,720	198,720	201,960
Gross cloth area, ft²	155,520	155,520	178,200	211,140	211,140	211,140
Monitor height,[f] ft	100	100	100	100	100	100
Moisture, percent	1	1	1	1	1	1
Pressure drop, in.	3-5	3-5	3-5	3-5	3-5	3-5

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[a] From Table 6-2.

[b] 1 = DEC, canopy hood, open roof. 2 = DEC, segmented canopy hood, scavenger duct, cross-draft partitions, open/closed roof. 3 = DEC, segmented canopy hood, scavenger duct, cross-draft partitions, closed roof. 4 = TFE, canopy hood, closed roof.

[c] From Table 6-10.

[d] At temperature noted.

[e] One compartment off-line for cleaning.

[f] Fabric filter monitor height above grade.

TABLE 6-8. MODEL FURNACE PARAMETERS--SPECIALTY STEEL FABRIC FILTER INFORMATION[1]
(Metric units)

Furnace type[a] Capture equipment[b] Regulatory alternative[c]	A 1 1	A 2 2	A 3 3	B 1 1	B 2 2	B 3 3	E 4 1	E 5 2	E 6 3
Air flow rate, m^3/s[d]									
Total	45.4	45.4	47.7	181.7	181.7	191.1	55.4	55.4	60.1
Canopy	31.3	28.9	28.9	125.1	115.6	115.6	30.7	28.3	30.7
DEC	14.1	14.1	14.1	56.6	56.6	56.6	--	--	--
Scavenger	--	2.4	4.7	--	9.5	18.9	--	2.4	4.7
Close-fitting hood	--	--	--	--	--	--	24.7	24.7	24.7
Temperature, °C	121	121	121	121	121	121	121	121	121
No. compartments, total	8	8	7	20	20	17	8	8	8
No. bags, total	384	384	420	1,440	1,440	1,530	512	512	576
Bag type	----------	----------	----------	----------	Dacron® polyester	----------	----------	----------	----------
Net air-to-cloth ratio[e]	3.18:1	3.18:1	3.13:1	3.13:1	3.13:1	3.13:1	2.89:1	2.89:1	2.81:1
Gross air-to-cloth ratio	2.79:1	2.79:1	2.68:1	2.97:1	2.97:1	2.94:1	2.57:1	2.57:1	2.46:1
No. fans	2	2	2	5	5	5	3	3	3
Fan wattage, each	96,980	96,980	104,440	171,580	171,580	171,580	104,440	104,440	111,900
Net cloth area,[e] m^2	2,813.0	2,813.0	3,014.0	11,453.2	11,453.2	12,056.0	3,781.5	3,781.5	4,219.6
Gross cloth area, m^2	3,214.9	3,214.9	3,516.3	12,056.0	12,056.0	12,809.5	4,253.1	4,253.1	4,822.4
Monitor height,[f] m	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9
Moisture, percent	1	1	1	1	1	1	1	1	1
Pressure drop, cm	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7

(continued)

TABLE 6-8. (continued)
(Metric units)

Furnace type[a] Capture equipment[b] Regulatory alternative[c]	F 4 1	F 5 2	F 6 3	A, E 1, 4 1	A, E 2, 5 2	A, E 3, 6 3	B, F 1, 4 1	B, F 2, 5 2	B, F 3, 6 3
Air flow rate, m^3/s[d]									
Total	221.8	221.8	240.7	100.7	100.7	107.8	403.4	403.4	431.8
Canopy	122.7	123.2	112.7	61.9	57.2	59.6	247.7	228.8	238.3
DEC	--	--	--	14.1	14.1	14.1	56.6	56.6	56.6
Scavenger	--	9.5	18.9	--	4.7	9.4	--	18.9	37.8
Close-fitting hood	99.1	99.1	99.1	24.7	24.7	24.7	99.1	99.1	99.1
Temperature, °C	121	121	121	121	121	121	121	121	121
No. compartments, total	16	16	16	10	10	15	17	17	18
No. bags, total	1,920	1,920	2,112	880	880	900	3,332	3,332	3,582
Bag type	Dacron® polyester								
Net air-to-cloth ratio[e]	2.89:1	2.89:1	2.86:1	3.01:1	3.01:1	3.03:1	3.00:1	3.00:1	3.02:1
Gross air-to-cloth ratio	2.72:1	2.72:1	2.68:1	2.71:1	2.71:1	2.82:1	2.85:1	2.85:1	2.85:1
No. fans	6	6	6	4	4	4	6	6	6
Fan wattage, each	179,040	179,040	186,500	156,660	156,660	164,120	343,160	343,160	350,620
Net cloth area,[e] m	15,128.7	15,128.7	16,577.0	6,605.7	6,605.7	7,023.4	26,512.1	26,512.1	28,184.7
Gross cloth area, m^2	16,074.7	16,074.7	17,682.2	7,337.3	7,337.3	7,546.2	27,907.5	27,907.5	29,970.8
Monitor height,[f] m	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9
Moisture, percent	1	1	1	1	1	1	1	1	1
Pressure drop, cm	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7	7.6-12.7

[a] From Table 6-3.

[b] 1 = DEC, canopy hood, open roof.
2 = DEC, segmented canopy hood, scavenger duct, cross-draft partitions, open/closed roof.
3 = DEC, segmented canopy hood, scavenger duct, cross-draft partitions, closed roof.
4 = close-fitting hood, canopy hood, open roof.
5 = close-fitting hood, canopy hood, scavenger duct, cross-draft partitions, open/closed roof.
6 = close-fitting hood, canopy hood, scavenger duct, cross-draft partitions, closed roof.

[c] From Tables 6-10 and 6-11.

[d] At temperature noted.

[e] One compartment off-line for cleaning.

[f] Fabric filter monitor height above grade.

TABLE 6-9. MODEL FURNACE PARAMETERS--SPECIALTY STEEL FABRIC FILTER INFORMATION[1]
(English units)

Furnace type[a] Capture equipment[b] Regulatory alternative[c]	A 1 1	A 2 2	A 3 3	B 1 1	B 2 2	B 3 3	E 4 1	E 5 2	E 6 3
Air flow rate, acfm[d]									
Total	96,250	96,250	101,250	385,000	385,000	405,000	117,500	117,500	127,500
Canopy	66,250	61,250	61,250	265,000	245,000	245,000	65,000	60,000	65,000
DEC	30,000	30,000	30,000	120,000	120,000	120,000	--	--	--
Scavenger	--	5,000	10,000	--	20,000	40,000	--	5,000	10,000
Close-fitting hood	--	--	--	--	--	--	52,500	52,500	52,500
Temperature, °F	250	250	250	250	250	250	250	250	250
No. compartments, total	8	8	7	20	20	17	8	8	8
No. bags, total	384	384	420	1,440	1,440	1,530	512	512	576
Bag type	Dacron® polyester								
Net air-to-cloth ratio[e]	3.18:1	3.18:1	3.13:1	3.13:1	3.13:1	3.13:1	2.89:1	2.89:1	2.81:1
Gross air-to-cloth ratio	2.79:1	2.79:1	2.68:1	2.97:1	2.97:1	2.94:1	2.57:1	2.57:1	2.46:1
No. fans	2	2	2	5	5	5	3	3	3
Fan horsepower, each	130	130	140	230	230	230	140	140	150
Net cloth area,[e] ft^2	30,240	30,240	32,400	123,120	123,120	129,600	40,650	40,650	45,360
Gross cloth area, ft^2	34,560	34,560	37,800	129,600	129,600	137,700	45,720	45,720	51,840
Monitor height,[f] ft	75	75	75	75	75	75	75	75	75
Moisture, percent	1	1	1	1	1	1	1	1	1
Pressure drop, in.	3-5	3-5	3-5	3-5	3-5	3-5	3-5	3-5	3-5

(continued)

TABLE 6-9. (continued)
(English units)

Furnace type[a] Capture equipment[b] Regulatory alternative[c]	F 4 1	F 5 2	F 6 3	A, E 1, 4 1	A, E 2, 5 2	A, E 3, 6 3	B, F 1, 4 1	B, F 2, 5 2	B, F 3, 6 3
Air flow rate, acfm[d]									
Total	470,000	470,000	510,000	213,750	213,750	228,750	855,000	855,000	915,000
Canopy	260,000	240,000	260,000	131,250	121,250	126,250	525,000	485,000	505,000
DEC	--	--	--	30,000	30,000	30,000	120,000	120,000	120,000
Scavenger	--	20,000	40,000	--	10,000	20,000	--	40,000	80,000
Close-fitting hood	210,000	210,000	210,000	52,500	52,500	52,500	210,000	210,000	210,000
Temperature, °F	250	250	250	250	250	250	250	250	250
No. compartments, total	16	16	16	10	10	15	17	17	18
No. bags, total	1,920	1,920	2,112	880	880	900	3,332	3,332	3,582
Bag type	Dacron® polyester								
Net air-to-cloth ratio[e]	2.89:1	2.89:1	2.86:1	3.01:1	3.01:1	3.03:1	3.00:1	3.00:1	3.02:1
Gross air-to-cloth ratio	2.72:1	2.72:1	2.68:1	2.71:1	2.71:1	2.82:1	2.85:1	2.85:1	2.84:1
No. fans	6	6	6	4	4	4	6	6	6
Fan horsepower, each	240	240	250	210	210	220	460	460	470
Net cloth area,[e] ft	162,630	162,630	178,200	71,010	71,010	75,500	285,000	285,000	302,980
Gross cloth area, ft^2	172,800	172,800	190,080	78,875	78,875	81,120	300,000	300,000	322,180
Monitor height,[f] ft	75	75	75	75	75	75	75	75	75
Moisture, percent	1	1	1	1	1	1	1	1	1
Pressure drop, in.	3-5	3-5	3-5	3-5	3-5	3-5	3-5	3-5	3-5

[a] From Table 6-3.

[b] 1 = DEC, canopy hood, open roof.
2 = DEC, segmented canopy hood, scavenger duct, cross-draft partitions, open/closed roof.
3 = DEC, segmented canopy hood, scavenger duct, cross-draft partitions, closed roof.
4 = close-fitting hood, canopy hood, open roof.
5 = close-fitting hood, canopy hood, scavenger duct, cross-draft partitions, open/closed roof.
6 = close-fitting hood, canopy hood, scavenger duct, cross-draft partitions, closed roof.

[c] From Tables 6-10 and 6-11.

[d] At temperature noted.

[e] One compartment off-line for cleaning.

[f] Fabric filter monitor height above grade.

In general, the air flow rates shown in Table 6-5 are higher than those in use at the time of promulgation of the existing standards of performance. The increased air flow rates used today are due in part to shorter heat times (noted earlier) because the emissions are being generated over a shorter time span, requiring increased air flow for effective emissions capture. The increased flows have created a dilution effect on the fabric filter exhaust gas, lowering both emission concentration and opacity.

No emission control systems are required by the process or are used specifically for product recovery or worker safety (although these are side benefits of emissions capture). The fabric filter dust collected from AOD vessels and EAF's in specialty steel shops can be reclaimed to recover chrome, nickel, and iron. Carbon steel EAF shops use a variety of methods to recycle or reclaim the fabric filter dusts. Some of the methods include: (1) recycling the dust for the zinc content, (2) recharging the pelletized dust into the furnace, and (3) using the dust in the manufacture of fertilizer. Research is currently being conducted to explore all the alternatives for recycling or reclaiming the dust to reduce the expense of disposing of the dust in a landfill.

The EAF fabric filter dust has been classified as a hazardous waste under the provisions of the Resource Conservation and Recovery Act (RCRA) because of the lead, cadmium, and hexavalent chromium content.[8] The dust from an AOD vessel has not been classified. However, because the AOD vessel fabric filter dust also contains lead, cadmium, and hexavalent chromium, it may be assumed that AOD fabric filter dust will eventually be classified as a hazardous waste. In many cases, the dusts from the EAF and AOD vessel are collected in the same fabric filter and handled accordingly.

6.3 REGULATORY ALTERNATIVES

The EPA's decision on how to regulate emissions from EAF's and AOD vessels is based in part on an examination of various combinations of capture and control techniques. These combinations provide a basis for establishing varying levels of emission reduction and, thus, the various regulatory altneratives. Three such regulatory alternatives have been developed for EAF's and AOD vessels and are described below. Environmental, economic, and energy impacts of the alternatives are evaluated in later chapters.

Table 6-10 presents the regulatory alternatives for carbon and specialty steel shop EAF's. Table 6-11 provides regulatory alternatives for AOD vessels in the specialty steel shop facilities. Tables 6-10 and 6-11 also present the fugitive emissions capture technologies upon which the regulatory alternatives are based. Only the fugitive emissions capture systems and the percent emission reduction are presented in Tables 6-10 and 6-11. This is because improvement in the efficiency of fugitive emissions capture technology has been observed in the industry since the development of the existing standards of performance.

Regulatory Alternative 1 is termed the baseline and provides for no additional Federal regulatory action. The control of emissions would rely on existing local, State, or Federal regulations. The baseline emission limits for EAF's, dust-handling equipment, and AOD vessels are outlined in Section 3.3. Each successive alternative beyond the baseline (i.e., Alternatives 2 and 3) represents an increase in the level of emissions reduction achieved through the use of additional capture technologies and increased capture efficiency. All of the regulatory alternatives are based on the use of a fabric filter as the control device.

The fugitive emissions capture equipment for each alternative was selected for analysis based on those used at the facilities tested. The estimated fugitive emission reduction efficiencies of each of these capture equipment systems were based on review of the literature, observation of these technologies at the facilities tested, and engineering judgment. There may be other capture combinations or individual devices applicable in a particular situation but which are not widely used or suitable for universal application. For some furnace sizes, for example, total furnace enclosures (TFE's) can achieve the same emissions reduction as the equipment shown on Tables 6-10 and 6-11; however, these devices will be analyzed on a limited basis only because of limited operating experience with TFE's on larger furnaces.

TABLE 6-10. REGULATORY ALTERNATIVES--CARBON AND SPECIALTY STEEL EAF

Reg. alt.	Point of emissions	Estimated fugitive emission reduction,[a] percent	Fugitive emissions capture equipment[b]
1	Shop roof	75-85	Single canopy hood, open roof monitor; enclosed dust-handling equipment.
2	Shop roof	85-95	Segmented canopy hood, scavenger duct, cross-draft partitions (or single canopy hood with separate tapping and slagging hoods), closed roof (over furnace)/open roof monitor elsewhere; enclosed dust-handling equipment.
3	Shop roof	95-100	Segmented canopy hood, scavenger duct, cross-draft partitions, closed roof; enclosed dust-handling equipment.

[a] Estimate based on literature review, observation of technologies, and engineering judgment.

[b] DEC system used for process emissions capture on all alternatives. Fabric filters used for process and fugitive emissions control on all alternatives.

TABLE 6-11. REGULATORY ALTERNATIVES--SPECIALTY STEEL AOD VESSEL

Reg. alt.	Point of emissions	Estimated fugitive emission reduction,[a] percent	Fugitive emissions capture equipment[b]
1	Shop roof	75-85	Single canopy hood, open roof monitor.
2	Shop roof	85-95	Single canopy hood, scavenger duct, cross-draft partitions, closed roof (over vessel)/open roof monitor elsewhere; enclosed dust-handling equipment.
3	Shop roof	95-100	Single canopy hood, scavenger duct, cross-draft partitions, closed roof; enclosed dust-handling equipment.

[a] Estimate based on literature review, observation of technologies and engineering judgment.

[b] Close-fitting hood used for process emissions capture on all alternatives. Fabric filters are used to control all captured emissions.

6.4 REFERENCES FOR CHAPTER 6

1. Memo and attachments from Maxwell, W., Midwest Research Institute, to EAF files. September 16, 1981. Parameters used in model plant development.

2. Hess, G.W. Technology Leads the Way as Electric Furnace Steelmaking Heads for New Heights in the U.S. 33 Metal Producing. 18(7):41-48. July 1980.

3. Letter from Schwartz, S. M., American Iron and Steel Institute, to Banker, L. C., Midwest Research Institute. September 22, 1981. Information on EAF heat times and air flow rates.

4. Telecon. Terry, W., Midwest Research Institute, with Sarlitto, R., Union Carbide Corporation. September 9, 1981. Information on the use of EAF's and AOD vessels in the steel industry.

5. Telecon. Terry, W., Midwest Research Institute, with Askins, C., Babcock and Wilcox. September 9, 1981. Information about Babcock and Wilcox EAF/AOD facilities.

6. Telecon. Terry, W., Midwest Research Institute, with Bonaccorsi, A., Eastern Stainless Steel Company. September 9, 1981. Information on the use of EAF's and AOD vessels in the steel industry.

7. Telecon. Terry, W., Midwest Research Institute, with Cooley, C., American Iron and Steel Institute. September 14, 1981. Information on the use of EAF's and AOD vessels in the steel industry.

8. U.S. Environmental Protection Agency. Code of Federal Regulations. Title 40, Part 260, Subpart D and Appendix VII. Washington, D.C. Office of the Federal Register. May 19, 1980. pp. 33124 and 33132.

7. ENVIRONMENTAL IMPACTS

This chapter describes both the beneficial and adverse environmental impacts for each regulatory alternative described in Chapter 6. The impacts are either primary impacts, those attributable directly to the control device (e.g., reduced emission levels), or secondary impacts, those indirectly attributable to the operation of the control device (e.g., solid waste disposal).

The chapter contains evaluations of the impacts of the regulatory alternatives with respect to: (1) air pollution, (2) water pollution, (3) solid waste disposal, (4) energy use, and (5) other environmental impacts, such as noise pollution and the irreversible and irretrievable commitment of resources. These impacts are discussed for each model plant. To assess the effects of the standards of performance, the incremental impact of each regulatory alternative beyond the baseline level is evaluated.

7.1 AIR POLLUTION IMPACT

The most significant environmental impact of the regulatory alternatives is the incremental reduction in air pollution below the baseline emission levels. The following analysis discusses the impact of the annual reduction of particulate matter emissions and the associated effects on ambient air quality.

7.1.1 Emission Reductions

Annual particulate matter emission levels from the model furnaces for each of the regulatory alternatives are presented in Table 7-1. These emissions include fugitive emissions from the shop roof monitor and the emissions in the fabric filter exhaust. Table 7-2 shows the incremental reductions in the annual particulate matter emission levels

TABLE 7-1. ANNUAL PARTICULATE MATTER EMISSIONS FOR EACH MODEL FURNACE AND REGULATORY ALTERNATIVE[1]

Mg (tons)

Furnace/vessel:	EAF				AOD	
Model furnace:[a]	A	B	C	D	E	F
Furnace capacity: Mg (tons)	22.7 (25)	90.7 (100)	272.2 (300)	136.1 (150)	22.7 (25)	90.7 (100)
Reg. Alt. 0 (Uncontrolled)	561.3 (618.8)	2,449.4 (2,700.0)	8,940.5 (9,855.0)	6,522.3 (7,189.5)	299.3 (330.0)	1,306.4 (1,440.0)
Reg. Alt. 1 (Baseline)	12.8 (14.1)	55.8 (61.5)	203.6 (224.4)	148.5 (163.7)	6.7 (7.4)	29.4 (32.4)
Reg. Alt. 2	6.7 (7.4)	29.1 (32.1)	106.4 (117.3)	77.6 (85.6)	3.5 (3.9)	15.5 (17.1)
Reg. Alt. 3	0.5 (0.6)	2.4 (2.7)	9.0 (9.9)	6.5 (7.2)	0.3 (0.3)	1.3 (1.4)

[a] Refer to Chapter 6 for explanation of model furnace and regulatory alternative designation.

TABLE 7-2. ANNUAL PARTICULATE MATTER EMISSION REDUCTION BELOW UNCONTROLLED AND BASELINE LEVELS FOR EACH MODEL FURNACE/VESSEL SIZE
Mg (tons)

Furnace/vessel:	EAF				AOD vessel	
Model furnace:	A	B	C	D	E	F
Furnace capacity: Mg (tons)	22.7 (25)	90.7 (100)	272.2 (300)	136.1 (150)	22.7 (25)	90.7 (100)
Incremental reduction between alternatives						
0 and 1	548.5 (604.7)	2,393.6 (2,638.5)	8,736.9 (9,630.6)	6,373.8 (7,025.8)	292.6 (322.6)	1,277.0 (1,407.6)
0 and 2	554.6 (611.4)	2,420.3 (2,667.9)	8,834.1 (9,737.7)	6,444.7 (7,103.9)	295.8 (326.1)	1,290.9 (1,422.9)
0 and 3	560.8 (618.2)	2,447.0 (2,697.3)	8,931.5 (9,845.1)	6,515.8 (7,182.3)	299.0 (329.7)	1,305.1 (1,438.6)
1 and 2	6.1 (6.7)	26.7 (29.4)	97.2 (107.1)	70.9 (78.1)	3.2 (3.5)	13.9 (15.3)
1 and 3	12.3 (13.5)	53.4 (58.8)	194.6 (214.5)	142.0 (156.5)	6.4 (7.1)	28.1 (31.0)

below the uncontrolled level for each of the three regulatory alternatives and the incremental reductions for Regulatory Alternatives 2 and 3 below Regulatory Alternative 1.

Under all the regulatory alternatives, EAF's utilize the same process emission capture system, and the improved emission capture is the result of improvements in the fugitive emission capture technologies. Argon-oxygen decarburization vessels utilize the same fugitive emission capture for all the regulatory alternatives, and, as with EAF's, the improved emission capture is because of improved fugitive emission capture technologies. An additional benefit of increased capture and control efficiencies at various regulatory alternatives is the incremental reduction of trace metals and fluoride emissions to the atmosphere.

Table 7-3 presents the projected construction of model EAF/AOD facilities industry wide for each year between 1983 and 1987. This projected construction would result in an increase in industry wide EAF capacity from 1983 to 1987 of approximately 5.2 $\times 10^6$ Mg (5.73 $\times 10^6$ tons). Carbon steel EAF's account for 4.8 $\times 10^6$ Mg (5.29 $\times 10^6$ tons) of this increase, and specialty steel EAF's account for 0.40 $\times 10^6$ Mg (0.44 $\times 10^6$ tons). The growth in AOD vessel capacity during this same period, 1983 to 1987, is approximately 0.40 $\times 10^6$ Mg (0.44 $\times 10^6$ tons).

Table 7-4 presents the industry wide particulate matter emissions (from those facilities affected by revised standards of performance) based on the projected growth shown in Table 7-3. Both annual and 5-year cumulative emissions are presented for the uncontrolled case and for each regulatory alternative.

7.1.2 Ambient Air Quality Impact

The impact of the regulatory alternatives on air pollution is shown by their impact on ambient air quality. Dispersion modeling was used to predict the contribution of EAF's and AOD vessels to the ambient particulate concentration. The dispersion model used and the results obtained are discussed in the following subsections.

7.1.2.1 Model Description. The model used in this dispersion analysis was the Industrial Source Complex (ISC) model in the short-term mode (ISCST).[2,3] General data and options of the ISC model used are presented in Table 7-5. The ISC model requires input data on sources,

TABLE 7-3. PROJECTED CONSTRUCTION OF MODEL EAF/AOD PLANTS INDUSTRY WIDE, 1983-1987

Plants	1983	1984	1985	1986	1987	5-year total
Carbon steel						
90.7-Mg (100-ton) EAF's	2	0	3	0	3	8
136.1-Mg (150-ton) EAF's	1	1	1	1	1	5
272.2-Mg (300-ton) EAF's	0	1	0	1	0	2
Specialty steel						
22.7-Mg (25-ton) EAF/AOD	0	1	0	1	0	2
90.7-Mg (100-ton) EAF/AOD	1	0	1	0	0	2

TABLE 7-4. TOTAL PARTICULATE MATTER EMISSIONS FOR NEW SHOPS ADDED IN 1983-1987 AND 5-YEAR CUMULATIVE Mg/yr (tons/yr)

Regulatory Alternative	1983	1984	1985	1986	1987	5-year cumulative
Carbon steel shops						
Uncontrolled	11,472.0 (12,645.0)	15,595.0 17,190.0)	13,907.0 (15,330.0)	15,595.0 (17,190.0)	13,907.0 (15,330.0)	206,556.0 (227,685.0)
1	261.3 (288.0)	355.2 (391.5)	316.7 (349.1)	355.2 (391.5)	316.7 (349.1)	4,704.5 (5,185.7)
2	136.5 (150.5)	185.6 (204.6)	165.6 (182.5)	185.6 (204.6)	165.6 (182.5)	2,458.5 (2,710.0)
3	11.4 (12.6)	15.6 (17.2)	13.9 (15.3)	15.6 (17.2)	13.9 (15.3)	206.2 (227.3)
Specialty steel shops						
Uncontrolled	3,798.0 (4,186.0)	805.4 (887.8)	3,798.0 (4,186.0)	805.4 (887.8)	0 0	35,213.0 (38,815.0)
1	86.1 (94.9)	18.2 (20.1)	86.1 (94.9)	18.2 (20.1)	0 0	798 (879.8)
2	45.2 (49.8)	9.6 (10.6)	45.2 (49.8)	9.6 (10.6)	0 0	419.2 (462.1)
3	3.8 (4.2)	0.8 (0.9)	3.8 (4.2)	0.8 (0.9)	0 0	35.2 (38.8)

TABLE 7-5. GENERAL DATA AND OPTIONS OF ISCST MODEL USED IN ATMOSPHERIC DISPERSION MODELING ANALYSIS[4,5]

Data item	Description/option
SOURCE DATA	
Pollutant	· Particulate matter.
Particle size	· EAF: 0.5-1.0 μm (64%) 5.0-10.0 μm (20%) 10.0-20.0 μm (4%) 20.0-40.0 μm (6%) 40.0-50.0 μm (6%)
	· AOD: 0.1-0.5 μm (15%) 0.5-1.0 μm (22%) 1.0-2.5 μm (29%) 2.5-5.0 μm (10%) 5.0-10.0 μm (5%) 10.0-20.0 μm (19%)
	· EAF + AOD: 0.1-0.5 μm (49%) 0.5-1.0 μm (8%) 1.0-2.5 μm (10%) 2.5-5.0 μm (7%) 5.0-10.0 μm (6%) 10.0-20.0 μm (20%)
Particle settling	· Not included (based on insignificant differences in modeling results).
Averaging time	· Highest second-highest 24-hour values. · Annual geometric mean.
Special considerations	· Downwash of the plume in the wake of a nearby building.
METEOROLOGICAL DATA	
Year of data	· 1964 (last year of hourly records).
Geographic locations	· Pittsburgh, Pa. (valley terrain; 6.7% calm winds; variable wind direction).
	· Oklahoma City, Okla. (uniform terrain; 0.9% calm winds; predominant wind direction).
Setting	· Urban.

(continued)

TABLE 7-5. (continued)

Data item	Description/option
METEOROLOGICAL DATA (continued)	
Special considerations	• Line sources treated as one or more buoyant point sources (low wind speeds) and volume source centered in the cavity region of the building (moderate to high wind speeds).[4] (ISC option allows emission rates for each source to be different for categories of wind speed and stability classes.)
RECEPTOR DATA	• Locations of maximum (worst-case) ground level concentrations. • Receptors as close as 100 m to property boundary or three building heights downwind, whichever is greater. • Additional polar coordinate receptor rings at 200 m, 250 m, 300 m, 2,000 m and 20,000 m centered at the source. • Maximum concentration impact sector only in final model runs, at 10° intervals: Pittsburgh, Pa. (30° to 90°) Oklahoma City, Okla. (310° to 10°). • Receptors at same elevation as plant grade.

meteorology, and receptors. These items are described in the following subsections.

7.1.2.1.1 Source data. Emissions from EAF's and AOD vessels are either vented through fabric filters or released directly through roof monitors. Both the fabric filters and roof monitors can be modeled as slightly buoyant line sources. A typical configuration of the melt shop furnace building (with the roof monitor open across the length of the furnace building) and fabric filter is shown in Figure 7-1. This configuration represents a worst-case arrangement for downwind concentration impacts.

In this modeling effort, particulate emissions were considered to be gaseous emissions, i.e., as though the particles would not settle out. As indicated in Table 7-5, approximately 80 percent of the particles from an EAF, AOD vessels, or EAF plus AOD vessels combination are smaller than 10 micrometers (μm). Analysis of modeling results, with particle settling and without particle settling, indicated that differences in downwind concentration impacts were less than 3 percent. For this reason, particle settling was not considered in the final computer modeling runs.

The following data are required by the ISC model for line sources:

1. Emission height (m);
2. Exit dimensions (m);
3. Exit velocity (m/s);
4. Exit temperature (K); and
5. Particulate emission rate (g/s).

Tables 7-6 and 7-7 summarize the source characteristics of each model furnace and regulatory alternative (as described in Chapter 6) for fabric filter sources and roof monitor sources, respectively.

Downwash effects are also considered in the ISC model. As indicated in Tables 7-6 and 7-7, the source emission heights are low (i.e., 22.9 to 38.1 m). Emission gas streams such as those modeled (with low emission heights, low exit velocities, and temperatures close to ambient) have small plume rise and, thus, low effective emission height. These sources will be affected by aerodynamic downwash, resulting in maximum concentration impacts close to the source.

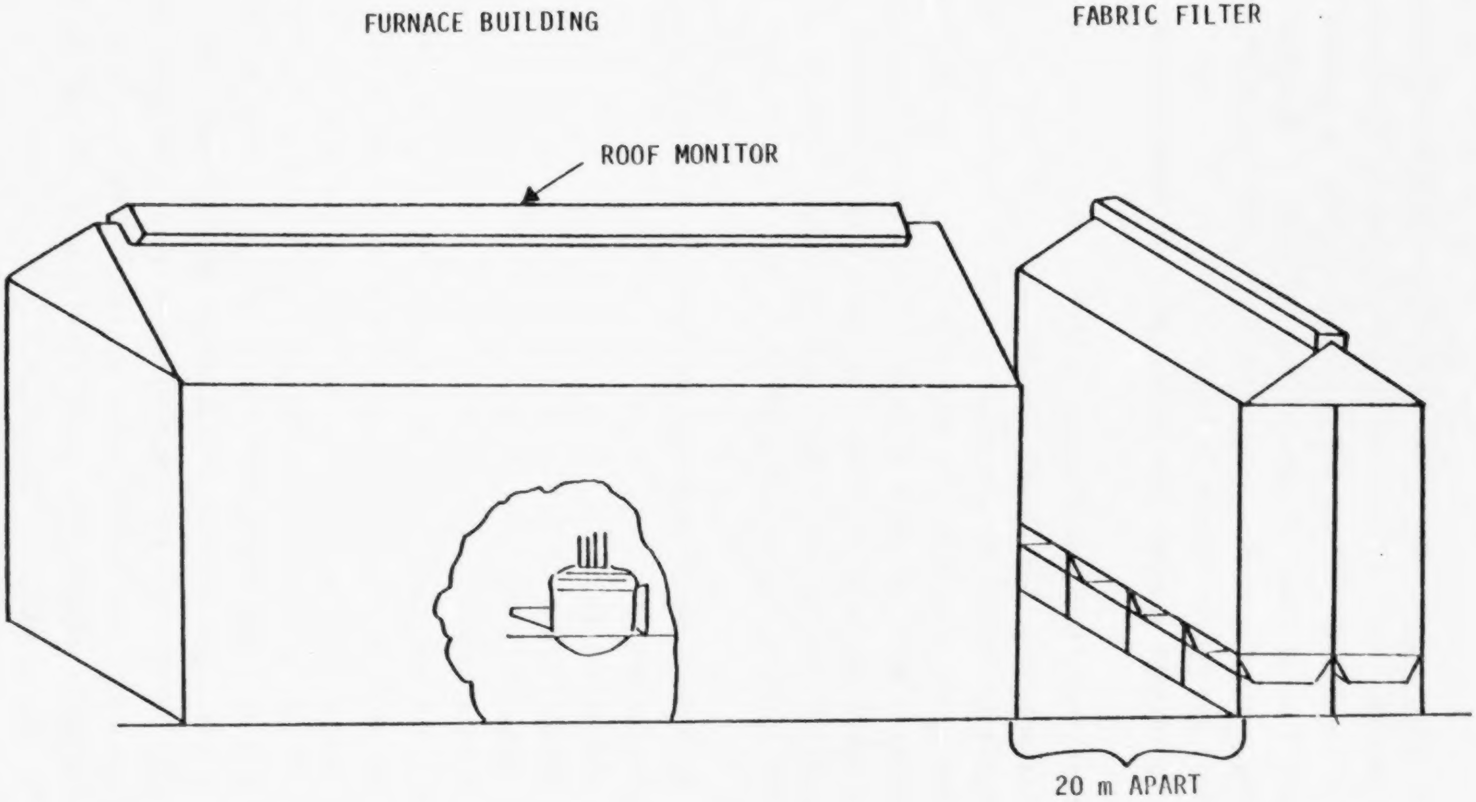
FURNACE BUILDING
FABRIC FILTER
ROOF MONITOR
20 m APART

Figure 7-1. Typical furnace building and fabric filter layout (with roof monitor open across furnace building).

TABLE 7-6. MODELING DATA FOR FABRIC FILTER SOURCES

Case No.[a,b]	Furnace ID[c]	Reg alt.	Emission height, m	Fabric filter monitor		Fabric filter width, m	Emission rate, g/s[d]	Operating time		Exit velocity m/s
				length, m	width, m			h/day	days/yr	
1	A	1	22.86	15.24	3.05	7.62	0.303	24	275	0.98
2	A	2	22.86	15.24	3.05	7.62	0.303	24	275	0.98
3	A	3	22.86	15.24	3.05	7.62	0.318, 0.223	24	275	1.03
4	B	1	22.86	15.24	3.05	13.72	1.210	24	300	3.91
5	B	2	22.86	15.24	3.05	13.72	1.210	24	300	3.91
6	B	3	22.86	15.24	3.05	13.72	1.273	24	300	4.11
7	C	1	30.48	22.86	3.05	15.24	1.462	24	365	3.15
8	C	2	30.48	22.86	3.05	15.24	1.462	24	365	3.15
9	C	3	30.48	22.86	3.05	15.24	1.273	24	365	3.55
10	D	1	30.48	22.86	3.05	15.24	1.886	24	355	4.06
11	D	2	30.48	22.86	3.05	15.24	1.886	24	355	4.06
12	D	3	30.48	22.86	3.05	15.24	1.980	24	355	4.26
13	A	1	22.86	15.24	3.05	7.62	0.303	24	275	0.98
14	A	2	22.86	15.24	3.05	7.62	0.303	24	275	0.98
15	A	3	22.86	15.24	3.05	7.62	0.318	24	275	1.03
16	B	1	22.86	22.86	3.05	15.24	1.210	24	300	2.60
17	B	2	22.86	22.86	3.05	15.24	1.210	24	300	2.60
18	B	3	22.86	22.86	3.05	15.24	1.273	24	300	2.74
19	E	1	22.86	15.24	3.05	7.62	0.185	24	275	1.40
20	E	2	22.86	15.24	3.05	7.62	0.185	24	275	1.24
21	E	3	22.86	15.24	3.05	7.62	0.200	24	275	1.30
22	F	1	22.86	22.86	3.05	15.24	0.739	24	300	3.72
23	F	2	22.86	22.86	3.05	15.24	0.739	24	300	3.32
24	F	3	22.86	22.86	3.05	15.24	0.802	24	300	3.45
25	A/E	1	22.86	15.24	3.05	13.72	0.487	24	275	2.37
26	A/E	2	22.86	15.24	3.05	13.72	0.487	24	275	2.22
27	A/E	3	22.86	15.24	3.05	13.72	0.519	24	275	2.32
28	B/F	1	22.86	38.10	3.05	28.96	1.949	24	300	3.80
29	B/F	2	22.86	38.10	3.05	28.96	1.949	24	300	3.55
30	B/F	3	22.86	38.10	3.05	28.96	2.075	24	300	3.72

[a] Cases 1 through 12 represent individual carbon steel facilities; cases 13 through 30 represent specialty steel shops.

[b] The cases can be grouped as follows for modeling:

Group 1: Cases 1-6, 13-15, 19-21, and 25-27.
Group 2: Cases 7-12.
Group 3: Cases 16-18 and 22-24.
Group 4: Cases 28-30.

[c] Furnace ID's A, B, C, and D are EAF's; furnace ID's E and F are AOD vessels.

[d] The exit temperature for all cases is 394°K.

TABLE 7-7. MODELING DATA FOR ROOF MONITOR SOURCES

Case No.[b]	Furnace ID[c]	Reg. alt.	Emission ht, m	Roof monitor length, m[a]					Emission rate, g/s[f]	Operating times		Exit temp. K	Exit velocity m/s
				Open 1[d]	Space 1[e]	Open 2[d]	Space 2[e]	Open 3[d]		h	days		
31	A	1	27.4	45.72	--	--	--	--	0.515	24	275	320	3.38
32	A	2	27.4	10.67	13.72	21.34	--	--	0.258	24	275	320	3.38
33	A	3	27.4	10.67	13.72	21.34	--	--	0.00	24	275	320	3.38
34	B	1	33.5	68.58	--	--	--	--	2.06	24	300	320	3.74
35	B	2	33.5	15.24	21.34	32.00	--	--	1.03	24	300	320	3.74
36	B	3	33.5	15.24	21.34	32.00	--	--	0.00	24	300	320	3.74
37	C	1	38.1	106.68	--	--	--	--	6.18	24	365	320	4.00
38	C	2	38.1	25.91	27.43	53.34	--	--	3.09	24	365	320	4.00
39	C	3	38.1	25.91	27.43	53.34	--	--	0.00	24	365	320	4.00
40	D	1	36.6	76.20	--	--	--	--	4.64	24	355	320	3.90
41	D	2	36.6	18.29	22.86	35.05	--	--	2.32	24	355	320	3.90
42	D	3	36.6	18.29	22.86	35.05	--	--	0.00	24	355	320	3.90
43	A/E	1	27.4	53.34	--	--	--	--	0.515/0.275	24	275	320/690	3.38/3.90
44	A/E	2	27.4	7.62	13.72	10.67	13.72	7.62	0.258/0.137	24	275	320/320	3.38
45	A/E	3	27.4	7.62	13.72	10.67	13.72	7.62	0.00/0.00	24	275	320/320	3.38
46	B/F	1	33.5	91.44	--	--	--	--	2.06/1.10	24	300	320/690	3.74/4.31
47	B/F	2	33.5	15.24	21.34	18.29	21.34	15.24	1.03/0.549	24	300	320/320	3.74
48	B/F	3	33.5	15.24	21.34	18.29	21.34	15.24	0.00/0.00	24	300	320/320	3.74

[a] Width is 3.05 m for all cases.
[b] Cases 31 through 42 represent individual carbon steel facilities; cases 43 through 48 represent specialty steel shops.
[c] Furnace ID's A, B, C, and D are EAF's; furnace ID's E and F are AOD vessels.
[d] Length of emission area.
[e] Distance between emission areas.
[f] Emissions are uniformly spread across area(s)

7.1.2.1.2 Meteorological data. Meteorological data required by the ISC model include hourly values (for an entire year) of:

1. Ambient temperature (K);
2. Wind speed (m/s);
3. Wind direction (nearest 10 degrees); and
4. Stability class.

Daily morning and afternoon mixing height data are also required and are interpolated internally in the ISC model to hourly values.

EAF and AOD vessel facilities were assumed to be located in urban areas and, therefore, include heat island effects. This option in the ISC model converts all stable hours to neutral stability. Differences of less than 10 percent were noted for impacts using the urban mode versus the rural mode in sample calculations.[4]

In this study, 1964 climatological data for Pittsburgh, Pennsylvania, and Oklahoma City, Oklahoma, were used for comparison purposes. Both data sets are reasonably consistent with meteorological conditions representing maximum or worst-case impacts. Maximum impacts occur when the wind direction persists within a narrow angular sector and moderate winds are predominant.

Pittsburgh is characterized by rolling-to-mountainous terrain, strong-to-moderate wind speeds, some persistent wind directions, neutral stability, and periods of calms. Oklahoma City, on the other hand, is located on relatively flat terrain. The climatological conditions are characterized by very persistent wind directions, moderate-to-high wind speeds, neutral stability, and few calms.

Climatological data from 1964 were used because these data are fairly complete on an hour-by-hour basis. These data are considered to be meteorologically representative although no claim can be made in terms of climatological normalcy. The ISC model rejects days with questionable wind directions (which are often associated with light winds).

As noted in Table 7-5, special considerations in the modeling effort were made. Specifically, all line sources were initially treated as nonbuoyant volume sources as recommended by the ICS model user's guide.[2] This resulted in high ground level concentration impacts at receptors close to the source. These concentrations occurred under low wind speed and constant wind directions, particularly when the Pittsburgh, Pennsylvania, meteorological data are used. The line sources were then treated as one or more buoyant point sources under low wind speeds and as a volume source centered in the cavity region of the building under moderate-to-high wind speeds. A more detailed description of the model revisions is given in reference 4.

7.1.2.1.3 Receptor locations. The ISC model calculates concentration impacts for receptors at specified radial distances from the center of the source. Receptors were located at distances of 200 m, 250 m, 300 m, 2,000 m, and 20,000 m at 10-degree intervals radially. In addition, the closest receptor was assumed to be at least 100 m or three building heights downwind, whichever is greater. For some cases in this modeling effort, this restriction meant that the first receptor ring had to be more than 100 m away from the edge of the source.

All receptors were assumed to be at the same elevation as plant grade. The only terrain effects included in the modeling were those implicitly contained in the meteorological data (causing differences in patterns of stability, wind speed, and wind direction for Pittsburgh, Pennsylvania, and Oklahoma City, Oklahoma).

7.1.2.2 Discussion of Dispersion Calculations. Hourly concentration impacts from each case are calculated by the ISC model. Concentrations are summed for each receptor and midnight-to-midnight averages are determined for each 24-hour period. Annual arithmetic mean concentrations are then calculated by the model for each receptor and converted to annual geometric mean concentration using the relationship between the arithmetic mean (m), the geometric mean (m_g), the standard geometric deviation (s_g), and by assuming the concentrations are lognormally distributed. This relationship is:

$$m_g = \frac{m}{\exp(0.5 \ln^2 s_g)}$$

Standard geometric deviations for particulate matter range from about 1.5 to 2.2. Thus, the annual geometric mean concentration is in the range of 75 to 95 percent of the annual arithmetic mean concentration.

Concentration estimates calculated by the ISC model are generally within a factor of 2 of measured ambient concentrations.

The modeled particulate matter concentration impacts can be compared to the National Ambient Air Quality Standards (NAAQS):

Averaging time	Standard type	Particulate concentration ($\mu g/m^3$)
24-hour maximum (not to be exceeded more than once per year)	Primary	260
	Secondary	150
Annual geometric mean	Primary	75
	Secondary	60

7.1.2.3 Twenty-Four Hour Maximum Concentration Impacts. Maximum 24-hour (highest second-highest) particulate matter concentration impacts are presented in Table 7-8 for Oklahoma City and Pittsburgh for each of the regulatory alternatives for fabric filter sources. The maximum highest second-highest concentration is indicated for each case; for all cases, the maximum highest second-highest concentration impact occurred at the closest receptor to the source. As indicated in Table 7-8, concentration impacts for Pittsburgh and Oklahoma City are similar. In all cases, the Oklahoma City concentration impacts are slightly higher.

The maximum 24-hour concentration impact occurred for cases 28 through 30. These cases showed impacts of approximately 60 $\mu g/m^3$; this is well below the NAAQS. There is no significant difference between regulatory alternatives for a specific furnace type.

Similarly, maximum 24-hour (highest second-highest) particulate matter concentration impacts are presented in Table 7-9 for Oklahoma City and Pittsburgh for each of the cases for roof monitor sources. The maximum highest second-highest concentration is indicated for each case; for all cases the maximum highest second-highest concentration impact occurred at the closest receptor to the source.

As indicated in Table 7-7, the roof monitor emission rate for Regulatory Alternative 3 is zero. There is a significant reduction in concentration

TABLE 7-8. HIGHEST SECOND-HIGHEST 24-HOUR PARTICULATE MATTER CONCENTRATION IMPACTS FROM FABRIC FILTER SOURCES[4]

Case No.[a]	Furnace ID[b]	Regulatory alternative	Distance from source center to receptor (m)	Concentration impact (μg/m^3)	
				Pittsburgh	Oklahoma City
1	A	1	165	14.0	14.5
2	A	2	165	14.0	14.5
3	A	3	165	14.7, 10.3[c]	15.2, 10.7[c]
4	B	1	165	56.1	57.8
5	B	2	165	56.1	57.8
6	B	3	165	59.0	60.8
7	C	1	204	36.2	39.3
8	C	2	204	36.2	39.3
9	C	3	204	40.8	44.3
10	D	1	204	46.6	50.7
11	D	2	204	46.6	50.7
12	D	3	204	49.0	53.2
13	A	1	165	14.0	14.5
14	A	2	165	14.0	14.5
15	A	3	165	14.7	15.2
16[d]	B	1	165	53.3	54.9
17[d]	B	2	165	53.3	54.9
18[d]	B	3	165	56.0	57.8
19	E	1	165	8.6	8.8
20	E	2	165	8.6	8.8
21	E	3	165	9.3	9.6
22[d]	F	1	165	32.5	33.5
23[d]	F	2	165	32.5	33.5
24[d]	F	3	165	35.3	36.4
25	A/E	1	165	22.6	23.3
26	A/E	2	165	22.6	23.3
27	A/E	3	165	24.0	24.8
28	B/F	1	209	53.4	61.0
29	B/F	2	209	53.4	61.0
30	B/F	3	209	56.8	64.9

[a] Cases 1 through 12 represent individual carbon steel facilities; cases 13 through 30 represent specialty steel shops.

[b] Furnace ID's A, B, C, and D are EAF's; furnace ID's E and F are AOD vessels.

[c] Based on different air flow/rates and thus different emission rates (see Table 7-6).

[d] Extrapolated from data in References 4 and 5.

impacts for each regulatory alternative of a given furnace type. Also indicated in Table 7-9 are concentration effects with and without the buoyancy correction (as described in Section 7.1.2.1.2). For the cases modeled with buoyancy, the Pittsburgh impacts are in all cases lower than the same cases modeled without buoyancy at a 300-m distance. The Oklahoma City impacts modeled with buoyancy are all approximately the same as the cases modeled without buoyancy at a 100-m distance.

The maximum concentration impacts occurred for case 37. Combination of case 7 and case 37 indicates a 24-hour concentration of approximately 210 $\mu g/m^3$. This is below the primary NAAQS. In addition, all highest second-highest concentration impacts decreased monotonically for downwind distances of 250 m, 300 m, 2,000 m, and 20,000 m for all sources.[4]

7.1.2.4 Annual Geometric Mean Concentration Impacts. Maximum annual arithmetic mean concentrations are presented in Table 7-10 for Oklahoma City and Pittsburgh for each of the regulatory alternatives for fabric filter sources. As indicated in Section 7.1.2.2, the annual arithmetic mean concentration is slightly higher than the annual geometric mean concentration. In addition, assumed background levels (e.g., 30 to 50 $\mu g/m^3$) are not included in the values reported in Table 7-10. As in the 24-hour concentration results, the concentration impacts are slightly greater in Oklahoma City than in Pittsburgh.

The maximum annual concentration impacts are 14.7 $\mu g/m^3$ to 15.6 $\mu g/m^3$ for cases 28 through 30 for the three regulatory alternatives. These are well below the primary and secondary NAAQS's. In all cases, the impacts for Oklahoma City impacts are somewhat higher than those for Pittsburgh.

Similarly, maximum annual arithmetic mean concentrations are presented in Table 7-11 for Oklahoma City and Pittsburgh for each regulatory alternative for roof monitor sources. As in the 24-hour concentration results, there is a significant reduction in concentration impacts for each regulatory alternative for a specific furnace type.

In all cases, the annual concentration impacts are less than the primary NAAQS if a background value of 30 $\mu g/m^3$ were used.

TABLE 7-9. HIGHEST SECOND-HIGHEST 24-HOUR PARTICULATE MATTER CONCENTRATION IMPACTS FROM ROOF MONITOR SOURCES

Case No.[a]	Furnace ID[b]	Reg. alt.	Concentration impact ($\mu g/m^3$)							
			Pittsburgh				Oklahoma City			
			Without buoyancy		With buoyancy		Without buoyancy		With buoyancy	
			at 100 m	at 300 m			at 100 m	at 300 m		
31	A	1	44.0	25.3	23.9	at 165 m[c]	23.6	14.0	24.6	at 165 m
32	A	2	22.0	12.6	12.0		11.9	7.0	12.3	
33	A	3	0	0	0		0	0	0	
34	B	1	113	71.5	NM[d]		68.4	38.8	NM	
35	B	2	52.8	35.5	NM		30.0	18.5	NM	
36	B	3	0	0	0		0	0	0	
37	C	1	226	170	NM		124	86.7	NM	
38	C	2	111	84.7	NM		62.3	40.7	NM	
39	C	3	0	0	0		0	0	0	
40	D	1	199	139	96.9	at 204 m	112	74.4	111	at 204 m
41	D	2	118	84.3	57.3		68.7	43.3	62.4	
42	D	3	0	0	0		0	0	0	
43	A/E	1	65.9	38.8	NM		35.0	21.5	NM	
44	A/E	2	32.7	19.4	NM		17.4	13.3	NM	
45	A/E	3	0	0	0		0	0	0	
46	B/F	1	167	107	67.7	at 209 m	83.3	56.7	83.9	at 209 m
47	B/F	2	79.8	53.3	44.5		39.8	27.4	49.6	
48	B/F	3	0	0	0		0	0	0	

[a] Cases 31 through 42 represent individual carbon steel facilities; cases 43 through 48 represent specialty steel shops.

[b] Furnace ID's A, B, C, and D are EAF's; furnace ID's E and F are AOD vessels.

[c] Distance from source center to receptor.

[d] NM = Not modeled with buoyancy correction. Pittsburgh impacts are estimated to be less than impacts at 300 m modeled without buoyancy. Similarly, Oklahoma City impacts are estimated to be about the same as the 100 m impacts modeled without buoyancy.

TABLE 7-10. MAXIMUM ANNUAL ARITHMETIC MEAN PARTICULATE MATTER CONCENTRATION IMPACTS FROM FABRIC FILTER SOURCES

Case No.[a]	Furnace ID[b]	Regulatory alternative	Concentration impact excluding background, μg/m³	
			Pittsburgh	Oklahoma City
1	A	1	2.0	3.2
2	A	2	2.0	3.2
3	A	3	2.1, 1.5	3.3, 2.3
4	B	1	8.1	12.7
5	B	2	8.1	12.7
6	B	3	8.6	13.4
7	C	1	6.0	11.0
8	C	2	6.0	11.0
9	C	3	6.8	12.5
10	D	1	7.7	14.2
11	D	2	7.7	14.2
12	D	3	8.1	14.9
13	A	1	2.0	3.2
14	A	2	2.0	3.2
15	A	3	2.1	3.3
16	B	1	7.7	12.1
17	B	2	7.7	12.1
18	B	3	8.1	12.7
19	E	1	1.2	1.9
20	E	2	1.2	1.9
21	E	3	1.3	2.1
22	F	1	4.7	7.4
23	F	2	4.7	7.4
24	F	3	5.1	8.0
25	A/E	1	3.3	5.1
26	A/E	2	3.3	5.1
27	A/E	3	3.5	5.5
28	B/F	1	8.0	14.7
29	B/F	2	8.0	14.7
30	B/F	3	8.5	15.6

[a] Cases 1 through 12 represent individual carbon steel shops; cases 13 through 30 represent specialty steel shops.

[b] Furnace ID's A, B, C, and D are EAF's; furnace ID's E and F are AOD vessels.

TABLE 7-11. MAXIMUM ANNUAL ARITHMETIC MEAN PARTICULATE MATTER CONCENTRATION IMPACTS FROM ROOF MONITOR SOURCES

Case No.[a]	Furnace ID[b]	Regulatory alternative	Concentration impact excluding background,[c] μg/m^3 Pittsburgh	Oklahoma City
31	A	1	3.1	5.4
32	A	2	1.6	2.7
33	A	3	0	0
34	B	1	NM[d]	NM
35	B	2	NM	NM
36	B	3	0	0
37	C	1	NM	NM
38	C	2	NM	NM
39	C	3	0	0
40	D	1	16.5	33.7
41	D	2	9.9	17.8
42	D	3	0	0
43	A/E	1	NM	NM
44	A/E	2	NM	NM
45	A/E	3	0	0
46	B/F	1	9.2	20.5
47	B/F	2	7.3	12.4
48	B/F	3	0	0

[a] Cases 31 through 42 represent individual carbon steel facilities; cases 43 through 48 represent specialty steel shops.

[b] Furnace ID's A, B, C, and D are EAF's; furnace ID's E and F are AOD vessels.

[c] With buoyancy correction.

[d] NM = Not modeled with buoyancy correction; however, modeled without buoyancy correction, the annual concentration impacts were well below the NAAQS even with an assumed background concentration of 50 μg/m^3.

7.2 WATER POLLUTION IMPACT

The emission control device most likely to be used in the future is the fabric filter rather than electrostatic precipitators or wet scrubbers. It is not likely that water sprays will be used to cool the exhaust gases since ambient air is usually used to cool the gases. A heat exchanger could be used to cool the exhausts from direct fume extraction, such as the DEC on the EAF and the close-fitting hood on the AOD vessel.

Water-cooled ductwork for direct fume extraction and (e.g., EAF-DEC, AOD-close fitting hood) water-cooled furnace walls and roofs is expected to see greater use in the future, but this water use will not present a water pollution problem because the water is in a closed-loop cooling system and will not become contaminated.

7.3 SOLID WASTE DISPOSAL IMPACT

The quantities of solid waste (i.e., dust captured by the fabric filter) generated per year for each model plant are presented in Table 7-12. The increase in the amount of EAF fabric filter dust that will be captured by improved fugitive emissions capture will be small compared to the amount of dust already captured by present (baseline) emission capture systems. Furthermore, these solid wastes are a small portion of total steel mill solid wastes (e.g., slag).

Table 7-13 presents a summary of the quantities of solid waste generated nationwide from fabric filters controlling emissions from EAF's. For each regulatory alternative, the quantities of solid waste generated from emission control equipment were calculated for 1 to 5 years after proposal of the revised standards of performance. A summary of nationwide solid waste generated for AOD vessels is presented in Table 7-14. The incremental increase in the fabric filter dust generated from AOD vessel operation was also calculated for each regulatory alternative for 1 to 5 years after the proposal of the revised standards of performance.

The chemical analyses of the exhaust gases from EAF and AOD facilities were mentioned in Section 3.3.1. The dust collected from the EAF fabric filter has been classified as hazardous waste due to the presence of lead, cadmium, and hexavalent chromium.[2,3] The dust collected from AOD vessels has not been classified, but since it also contains lead, cadmium,

TABLE 7-12. SOLID WASTE (FABRIC FILTER CATCH) GENERATION FOR EACH MODEL PLANT[a],[1]
Mg/yr (tons/yr)

Furnace/vessel:	EAF				AOD	
Model furnace:	A	B	C	D	E	F
Furnace capacity:						
Mg (tons)	22.7 (25)	90.7 (100)	272.2 (300)	136.1 (150)	22.7 (25)	90.7 (100)
Furnace annual production:						
Mg (tons)	37,420 (41,250)	163,300 (180,000)	596,000 (657,000)	434,800 (479,300)	37,420 (41,250)	163,300 (180,000)
Regulatory alternative						
1	548.5 (604.7)	2,393.6 (2,638.5)	8,736.9 (9,630.6)	6,373.8 (7,025.8)	292.6 (322.6)	1,277.0 (1,407.6)
2	554.6 (611.4)	2,420.3 (2,667.9)	8,834.1 (9,737.7)	6,444.7 (7,103.9)	295.8 (326.1)	1,290.9 (1,422.9)
3	560.8 (618.2)	2,247.0 (2,697.3)	8,931.5 (9,845.1)	6,515.8 (7,182.3)	299.0 (329.7)	1,305.1 (1,438.6)

[a] Assuming 99.9 percent fabric filter capture efficiency.

TABLE 7-13. SUMMARY OF POTENTIAL INDUSTRY WIDE SOLID WASTE
GENERATION FROM FABRIC FILTERS--CARBON STEEL INDUSTRY
Mg/yr (tons/yr)

No. of facilities with model furnace size[a]	1983	1984	1985	1986	1987	5-year cumulative
B	2	0	3	0	3	8
C	0	1	0	1	0	2
D	1	1	1	1	1	5
Reg. Alt. 1	11,210 (12,360)	15,240 (16,800)	13,590 (14,980)	15,240 (16,800)	13,590 (14,980)	201,900 (222,500)
Reg. Alt. 2	11,340 (12,500)	15,410 (16,990)	13,740 (15,150)	15,410 (16,990)	13,740 (15,150)	204,100 (225,000)
Increase in solid wastes due to Reg. Alt. 2	130 (140)	170 (190)	150 (170)	170 (190)	150 (170)	2,200 (2,500)
Reg. Alt. 3	11,460 (12,630)	15,580 (17,170)	13,900 (15,320)	15,580 (17,170)	13,900 (15,320)	206,400 (227,500)
Increase in solid wastes due to Reg. Alt. 3	250 (270)	340 (370)	310 (340)	340 (370)	310 (340)	4,500 (5,000)

[a] Explanation of model furnaces in Chapter 6:
B = 90.7-Mg (100-ton) EAF
C = 272-Mg (300-ton) EAF
D = 136-Mg (150-ton) EAF

TABLE 7-14. SUMMARY OF POTENTIAL INDUSTRY WIDE SOLID WASTE GENERATION FROM FABRIC FILTERS--SPECIALTY STEEL INDUSTRY

Mg/yr (tons/yr)

No. of furnaces/ vessel combination[a]	1983	1984	1985	1986	1987	5-year cumulative
A/E	0	1	0	1	0	2
B/F	1	0	1	0	0	2
Reg. Alt. 1	3,711 (4,091)	787 (868)	3,711 (4,091)	787 (868)	0 0	34,410 (37,940)
Reg. Alt. 2	3,752 (4,136)	796 (877)	3,752 (4,136)	796 (877)	0 0	34,790 (38,350)
Increase in solid waste due to Reg. Alt. 2	41 (45)	9 (9)	41 (45)	9 (9)	0 0	380 (410)
Reg. Alt. 3	3,794 (4,182)	805 (887)	3,794 (4,182)	805 (887)	0 0	35,180 (38,780)
Increase in solid waste due to Reg. Alt. 3	83 (91)	18 (19)	83 (91)	18 (19)	0 0	770 (840)

[a] Explantion of model plants in Chapter 6:

A/E = one each 22.7-Mg (25-ton) EAF and AOD
B/F = one each 90.7-Mg (100-ton) EAF and AOD

and hexavalent chromium, it is assumed that it will also be a hazardous waste.[4] Furthermore, dusts from both EAF and AOD vessels are, in many cases, controlled by the same control device. Under the provisions of the Resource Conservation and Recovery Act (RCRA), hazardous waste must be either collected, separated, and recovered for reuse, or the nonrecoverable residues must be disposed of in an environmentally safe manner.[3]

The hazardous solid waste collected by the fabric filter can either be transferred to a landfill or recycled to the furnace. Currently, the use of landfills is predominant, but some recycling is performed and research is underway to enumerate the options available for recycling.[5] One plant directly injects the dust into the EAF while another forms dust briquettes, which are charged back into the furnace. Experimental reclamation of zinc from EAF fabric filter dust has been successfully performed for steel mills that use galvanized scrap. The zinc concentration has to be increased to 50 to 60 percent by weight before zinc smelters can use the zinc.[5]

Several specialty steel companies in the northeastern United States have their dust recycled at an offsite reclamation plant. The dust is reclaimed for the nickel (Ni), chromium (Cr), and iron (Fe) content, and the resulting product contains 12 percent Ni, 17 percent Cr, and 71 percent Fe.[6] The reclamation plant sells the reclaimed metals back to the steel companies at a percentage of the current market price of the metals.

Recycling would reduce the solid waste disposal impact related to the increased emission capture effectiveness of the various regulatory alternatives. Furthermore, it would prevent permanent loss of expensive alloys and reduce the raw material usage.

7.4 ENERGY IMPACT

Fabric filters are used and will continue to be used to meet the emission limits for both the baseline and regulatory alternatives. The impact of incremental increase in energy use associated with improved fugitive emissions capture is minimal (see Table 7-15). This incremental use is small because the regulatory alternatives (see Chapter 6) call

TABLE 7-15. INDUSTRY WIDE ELECTRICAL ENERGY REQUIREMENTS FOR 1983-1987 AND 5-YEAR CUMULATIVE (kWh/yr)

Regulatory alternative	1983	1984	1985	1986	1987	5-year cumulative[a]
Carbon steel						
1	23,657,000	18,694,000	30,451,000	18,694,000	30,451,000	352,253,000
2	23,657,000	18,694,000	30,451,000	18,694,000	30,451,000	352,253,000
3	24,076,000	20,839,000	30,871,000	20,839,000	30,871,000	368,898,000
Specialty steel						
1	16,307,000	4,549,000	16,307,000	4,549,000	--	157,750,000
2	16,307,000	4,549,000	16,307,000	4,549,000	--	157,750,000
3	16,661,000	4,766,000	16,661,000	4,766,000	--	161,884,000

[a] Cumulatives are in kWh.

for improved use of baseline equipment with partially or totally closed furnace shop roofs, cross-draft partitions, and scavenger duct systems.

An experimental system that uses a heat exchanger to recycle AOD vessel heat is in operation on the offgas duct of a close-fitting hood of an AOD vessel.[7] This system is used to heat the shop during the winter months and represents a means to reduce overall energy consumption. Also, a European steelmaker recycles the heat from EAF water-cooled side panels for heating purposes. The energy recovered can also be used for low pressure steam, preheating boiler water, desalinating brackish sea water, and various other purposes.[8]

7.5 OTHER ENVIRONMENTAL IMPACTS

No increase in noise level over those existing under baseline control is expected with any of the regulatory alternatives. Somewhat larger fans (located outside the melt shop) might be needed to comply with the emission levels outlined in some of the regulatory alternatives, but the increased noise level is still low compared to the EAF shop noise levels. On the other hand, if total or partial furnace enclosures are used to improve emission capture, the noise level in the furnace shop will be reduced.

7.6 OTHER ENVIRONMENTAL CONCERNS

7.6.1 Long-Term Gains/Losses

Increased emission control of the air pollutants resulting from the operation of the EAF's and AOD vessels would result in improved air quality. The long-term gains achieved by the regulatory alternatives result from reducing particulate matter, trace metals, inhalable particulates, and fluoride emissions to the ambient air. There would be a minimal increase in the amount of energy used. More solid waste will be generated as a result of improved fugitive emissions capture. Improved capture would improve shop internal environment as well as the ambient air. If the larger quantities of solid waste collected were recycled, considerable quantities of raw materials would be saved, thereby decreasing the cost of the final product.

7.6.2 Irreversible and Irretrievable Commitment of Resources

The increased quantities of fabric filter dust generated due to the incremental improvement in fugitive emissions capture required by the regulatory alternatives will increase the amount of solid waste generated. The solid waste disposal methods employed for the EAF and AOD vessel fabric filter dust that is not recycled may lead to an irreversible commitment of land. A majority of the discarded fabric filter dust is landfilled, and a lesser amount is stockpiled for future consideration of recycling.

The RCRA requires that the hazardous waste be delivered to a landfill that conforms with proper management practices. The principal objective of RCRA is to prevent contamination of ground water by wastes that could leak out of a nonhazardous waste landfill if the liner failed. The impact of the requirements of RCRA will be to stimulate interest in recycling the fabric filter dust to avoid the elevated disposal costs and to recover the expensive alloys that are added to the EAF and AOD vessel.

Use of the air pollution capture and control devices to achieve increased emission reduction would result in minor increased energy demands and represents a negligible irretrievable commitment of energy resources (i.e., coal, oil, natural gas, or nuclear fuel).

7.6.3 Environmental Impact of Delayed Standards

The impact of delaying the standards will be the continued discharge of fugitive emissions. The incremental benefits discussed in Section 7.1 would not be achieved as long as the standard is delayed.

7.7 REFERENCES FOR CHAPTER 7

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2. Bowers, J., J. Bjorkland, and C. Cheney. Industrial Source Complex (ICS) Dispersion Model User's Guide. Volume I. U.S. Environmental Protection Agency. Publication No. EPA-450/4-79-030. December 1979.

3. Bowers, J., J. Bjorkland, and C. Cheney. Industrial Source Complex (ICS) Dispersion Model User's Guide. Volume II. U.S. Environmental Protection Agency. Publication No. EPA-450/4-79-031. December 1979.

4. Stoeckenius, T., P. Gutfreund, and R. Morris. Further Dispersion Modeling Analyses of Particulate Control Regulatory Alternatives for Baghouse and Roof Monitor Sources in the Steel Industry. Prepared under EPA Contract No. 68-02-3582, Task 7. May 21, 1982.

5. Gutfreund, P., and R. Morris. Dispersion Modeling Analyses of Particulate Control Regulatory Alternatives for Baghouse and Roof Monitor Sources in the Steel Industry. Prepared under EPA Contract No. 68-02-3582, Task 1. December 15, 1981.

6. Letter and attachments from Andolina, A. V., AL Tech Specialty Steel Corporation to Iversen, R. E., EPA:ISB. August 21, 1980. Submittal of requested information.

7. U.S. Environmental Protection Agency. Code of Federal Regulations. Title 40, Part 260, Subpart D and Appendix VII. Washington, D.C. Office of the Federal Register. May 19, 1980. pp. 33124 and 33132.

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8. COSTS

This chapter presents the process and control costs for each of the model plants for new or retrofit and modified or reconstructed facilities. Emphasis is placed on the incremental control cost impacts of implementing the various regulatory alternatives presented in Chapter 6. The costs presented in the following sections provide input for the economic impact analysis described in Chapter 9. These control costs are dependent upon the model furnace parameters and the fabric filter and capture device parameters presented in Chapter 6. Any changes in those parameters, specifically in flue gas flow rates, may significantly impact the control costs.

8.1 COST ANALYSIS OF REGULATORY ALTERNATIVES

The capital and annualized costs for the process equipment in the new and retrofit model plants (Table 6-1, Chapter 6) are presented in Table 8-1. The model plant developed to account for modification will be described in Section 8.1.2. Model Plants 8 and 9 (Table 6-1, Chapter 6) in the specialty steel segment are subdivided into four model plants (in Table 8-1) to account for two control system configurations. The costs presented in Table 8-1 include the costs for the EAF/AOD vessel, melt shop building, transformer, cranes, ladles, teeming aisle or continuous caster, and other integral equipment in an EAF/AOD melt shop. Inclusion of the costs of these equipment items in the plant costs is necessary to estimate the economic and capital availability impacts of the regulatory alternatives (see Chapter 9). The plant costs were estimated from information derived from several sources and do not include the control system costs. The annualized costs consist of direct and indirect operating costs, including the capital recovery and scrap costs. The

TABLE 8-1. CAPITAL AND ANNUALIZED COSTS FOR UNCONTROLLED MODEL PLANTS[1-5]
(March 1981 dollars)

	Model plant	Production Mg/yr (tons/yr)	Capital costs[a] $10^6	Annualized costs[b] $10^6	Annualized costs[b] $/Mg[c]
1.	New shop: one 22.7-Mg (25-ton) EAF	37,420 (41,250)	7.0	8.9	238
2.	New shop: one 90.7-Mg (100-ton) EAF	163,300 (180,000)	20.0	28.7	176
3.	New shop: one 272.2-Mg (300-ton) EAF	596,000 (657,000)	25.6	89.8	150
4.	New shop: one 136.1-Mg (150-ton) UHP EAF	434,800 (479,300)	33.2	68.8	158
5.	One new 272.2-Mg (300-ton) EAF added to an existing shop	596,000 (657,000) (Additional)	17.0	88.3	148
6.	One new 22.7-Mg (25-ton) EAF added to an existing shop	37,420 (41,250) (Additional)	4.5	8.5	227
7.	New shop: EAF and AOD vessel, 22.7-Mg (25-ton) capacity each; separately controlled	37,420 (41,250)	14.6	18.8	502
8.	New shop: EAF and AOD vessel, 22.7-Mg (25-ton) capacity each; commonly controlled	37,420 (41,250)	14.6	18.8	502
9.	New shop: EAF and AOD vessel, 90.7-Mg (100-ton) capacity each; separately controlled	163,300 (180,000)	44.0	68.0	416
10.	New shop: EAF and AOD vessel, 90.7-Mg (100-ton) capacity each; commonly controlled	163,300 (180,000)	44.0	68.0	416

[a] Includes direct and indirect capital costs.
[b] Capital recovery and scrap costs are included.
[c] Costs are per megagram of steel produced.

capital recovery costs are based on an interest rate of 10 percent and an equipment life of 15 years. The estimated scrap costs are \$94.16/Mg (\$85.42/ton) for carbon steel shops and \$273.72/Mg (\$248.32/ton) for specialty steel shops.[6] A steel/scrap yield of 85 percent is assumed.

Table 8-2 presents the cost factors that are used to compute the control system capital costs. The cost factors for various items were developed as a function of control equipment cost from the information provided in the EPA study on the capital and operating costs of air pollution control systems. Similarly, Table 8-3 presents the bases for estimating the control system annualized costs.

Table 8-4 presents a summary of capital and annualized costs for the control systems utilized by the model plants under various regulatory alternatives. The control system capital costs include the purchase price of the fabric filter (control device) and the auxiliary equipment (such as capture devices, fans, ductwork, solid waste handling), and the direct and indirect installation costs. The control system and the capture equipment listed in Tables 6-6 through 6-9 of Chapter 6 for various furnaces under different regulatory alternatives were used to calculate the total capital costs of the overall control system. The solid waste handling equipment includes the pneumatic dust conveying system associated with the control system and the dust storage silo. The direct installation costs consist of the costs for foundation and supports, handling and erection, electrical wiring, piping, and painting. Similarly, the indirect installation costs are compiled by combining the engineering and supervision costs; construction and field expenses; construction fee; and startup, performance test, and contingencies costs.

Generally, the pollution control system costs range between 15 and 20 percent of the total plant costs at baseline levels. These cost percentages increase with increasing levels of control.

No secondary water treatment is required as a result of the air pollution control system because fabric filters will be the principal control technology. Therefore, no water treatment costs are included in the determination of the control costs shown in Table 8-4.

TABLE 8-2. COMPONENT CAPITAL COST FACTORS FOR FABRIC FILTERS AS A FUNCTION OF EQUIPMENT COST--NEW FACILITIES[7]
(March 1981 Dollars)

Cost element	Cost factor
Direct costs	
1. Purchased equipment	
Fabric filter - - - - - - - - - - - - A	
Auxiliary equipment (ductwork, canopies, continuous opacity monitor, dust removal system, and fan system) - - - - - B	
Instruments and controls - - - 0.15 (A+B)	
Taxes - - - - - - - - - - - - - - 0.03 (A+B)	
Freight - - - - - - - - - - - - - 0.05 (A+B)	
Base price (total of above) = 1.23 (A+B)	C
2. Direct installation costs	
Foundation and supports	0.04C
Handling and erection	0.75C
Electrical wiring	0.08C
Piping	0.01C
Painting	0.02C
Total	0.90C
Indirect costs	
3. Indirect installation costs	
Engineering and supervision	0.15C
Construction and field expenses	0.30C
Construction fee	0.10C
Start-up	0.01C
Performance test	0.01C
Contingencies	0.03C
Total	0.60C
Total capital costs (1 + 2 + 3)	2.50C

TABLE 8-3. BASIS FOR ESTIMATING ANNUALIZED COSTS--NEW FACILITIES[6-9]
(March 1981 Dollars)

Cost element	Cost factor
Direct operating costs	
1. Utilities	
A. Electricity	$0.0463/kWh
2. Operating labor	
A. Direct labor	$10.14/h; 6 h/day
B. Supervision	15% of 2A
3. Maintenance	
A. Labor (hourly rate of 10% premium over operating labor)	$11.15/h; 2 h/day
B. Material	100% of 3A
4. Visible emissions observer	$4,540
5. Flow monitoring	
A. Continuous	$25,000
B. Periodic	$13,600
6. Replacement Parts	
A. Bag replacement every 1.5 yr	Cost of bags/1.5
B. Filters for opacity monitors	$130
7. Solid waste transfer	$90/ton
Indirect operating costs	
8. Overhead	80% of 2A+2B+3A
9. Capital charges	
A. Administrative	2% of capital cost
B. Property tax	1% of capital cost
C. Insurance	1% of capital cost
D. Capital recovery factor[a]	0.1315

[a] Based on 10 percent interest rate and an equipment life of 15 years.

TABLE 8-4. SUMMARY OF CAPITAL AND ANNUALIZED COSTS OF POLLUTION CONTROL EQUIPMENT--EAF/AOD PROCESS AND FUGITIVE EMISSIONS[a] 10 (March 1981 dollars)

Model plant	Production Mg/yr (tons/yr)	Regulatory alternative	Capital costs[b]		Annualized costs	
			$\$10^6$	Percentage of total plant capital costs[c]	$\$10^3$	\$/Mg[d]
1. New shop: one 22.7-Mg (25-ton) EAF	37,420	1	1.73	19.8	500.8	13.38
	(41,250)	2	1.78	20.3	502.7	13.43
		3	1.81	20.5	514.9	13.76
		3[e]	1.71	19.7	482.2	12.87
2. New shop: one 90.7-Mg (100-ton) EAF	163,300	1	4.37	17.9	1,411.7	8.64
	(180,000)	2	4.52	18.4	1,433.2	8.78
		3	4.62	18.8	1,453.0	8.90
3. New shop: one 272.2-Mg (300-ton) EAF	596,000	1	4.87	16.0	2,230.5	3.74
	(657,000)	2	5.17	16.8	2,282.6	3.83
		3	5.57	17.9	2,441.3	4.10
4. New shop: one 136.1-Mg (150-ton) UHP EAF	434,800	1	6.29	16.0	2,316.9	5.33
	(479,300)	2	6.48	16.3	2,349.0	5.40
		3	6.67	16.7	2,404.0	5.53
5. One new 272.2-Mg (300-ton) EAF added to an existing shop	596,000	1	5.84	25.5	2,307.0	3.87
	(657,000)	2	6.20	26.7	2,360.9	4.15
	(Additional)	3	6.68	28.2	2,525.0	4.44
6. One new 22.7-Mg (25-ton) EAF added to an existing shop	37,420	1	2.08	31.6	518.0	13.84
	(41,250)	2	2.14	32.2	519.9	13.89
	(Additional)	3	2.17	32.5	532.6	14.23
		3[e]	2.05	31.3	498.7	13.33
7. New shop: EAF and AOD vessel, 22.7-Mg (25-ton) capacity each; separately controlled	37,420	1	3.59	19.7	933.7	24.95
	(41,250)	2	3.65	20.0	955.6	25.54
		3	3.77	20.5	989.0	26.43
8. New shop: EAF and AOD vessel, 22.7-Mg (25-ton) capacity each; commonly controlled	37,420	1	2.84	16.3	809.4	21.63
	(41,250)	2	2.90	16.6	813.1	21.73
		3	2.97	16.9	835.3	22.32
9. New shop: EAF and AOD vessel, 90.7-Mg (100-ton) capacity each; separately controlled	163,300	1	9.28	17.4	2,505.8	15.34
	(180,000)	2	9.45	17.7	2,545.9	15.59
		3	9.78	18.2	2,624.9	16.07
10. New shop: EAF and AOD vessel, 90.7-Mg (100-ton) capacity each; commonly controlled	163,300	1	8.45	16.1	2,371.7	14.52
	(180,000)	2	8.59	16.3	2,389.7	14.63
		3	8.99	17.0	2,479.7	15.18

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[a] Includes control device, capture devices, ductwork, and solid waste handling.

[b] Includes direct and indirect capital costs.

[c] Total plant investment includes the costs of the melt shop and the pollution control equipment.

[d] Costs are per megagram of steel produced.

[e] Costs are for total furnace enclosure (TFE) option. TFE costs were evaluated only for 22.7-Mg EAF's.

Regulatory Alternative 1 is the baseline alternative, which corresponds to the existing standards of performance for EAF's and the typical State regulations for AOD vessels. Regulatory Alternatives 2 and 3 represent more stringent levels of emission control. Facilities with EAF's regulated under Regulatory Alternative 1 are required to install a continuous opacity monitor to monitor the opacity of the visible emissions from the control device and to install flow monitors to monitor continuously the flows through the capture hoods. Under Regulatory Alternatives 2 and 3, EAF facilities can monitor the opacity of the visible emissions (VE) from the control device with a continuous opacity monitor or by visual observations made by a certified VE reader. These alternatives also allow periodic inspections of the capture system and once-per-shift recording of the key operating parameters (e.g., damper positions, fan amps, furnace static pressure) in lieu of continuous monitoring of the flows through the hoods. Adoption of the visual observation method and periodic inspections is very likely and has been assumed in calculating the capital costs for Regulatory Alternatives 2 and 3. The capital costs associated with monitoring by a certified VE reader are zero. The capital costs under Regulatory Alternatives 2 and 3 are higher than capital costs under Regulatory Alternative 1 because of higher costs for the control and capture systems, which offset the decrease in the costs related to the use of periodic monitoring.

Tables 8-5 and 8-6 present a detailed cost breakdown of the capital costs for fabric filter control systems for carbon and specialty steel facilities, respectively. The estimated purchase costs for air pollution control equipment agree well with the purchase costs of control systems bought by the industry in recent years.[1-3,11,12] The installation costs shown on Tables 8-5 and 8-6 may differ from those incurred by the industry because the nationwide average cost factors that were used in computing the costs on the table differ from site-specific installation costs.

The annualized costs for the control system include direct operating costs (e.g., utilities, labor, parts, VE observer, and solid waste transfer) and indirect operating costs (e.g., plant overhead, capital charges, and capital recovery costs).[10] The solid waste transfer costs for carbon steel shops are estimated at the rate of $90/ton because the

TABLE 8-5. CAPITAL COSTS FOR FABRIC FILTER CONTROL METHOD--NEW CARBON STEEL FACILITIES[10] (March 1981 Dollars)

Cost element							
Furnace type[a]	A	A	A	A	B	B	B
Capture equipment[b]	1	2	3	4	1	2	3
Model plant[c]	1[d]	1	1	1	2[d]	2	2
Regulatory alternative[e]	1	2	3	3	1	2	3
DIRECT COSTS							
1. Purchased Equipment Costs							
A. Primary							
Fabric filter	266,300	266,300	275,500	239,100	646,800	646,800	673,800
B. Auxiliary							
Canopy hood with dampers	13,150	18,000	17,700	11,100	30,750	41,200	40,200
DEC water-cooled duct (100 ft)	73,600	73,600	73,600	--	162,100	162,100	162,100
Total furnace enclosure	--	--	--	130,100	--	--	--
Scavenger duct with partitions[f]	--	25,600	25,600	--	--	53,400	53,400
Dust handling	30,300	30,300	30,300	30,300	45,800	45,800	45,800
Continuous opacity monitor	9,750	--	--	--	9,750	--	--
Continuous flow monitoring	4,900	--	--	--	4,900	--	--
Fan system	82,100	82,100	82,100	72,400	328,600	328,600	328,600
Ductwork (250 ft)	72,400	72,400	74,700	64,800	166,800	166,800	171,900
Emergency air dilution damper	9,900	9,900	10,300	8,800	25,000	25,000	25,800
Total (A + B)	562,400	578,200	589,800	556,600	1,420,500	1,469,700	1,501,600
Instruments and controls	84,300	86,700	88,500	83,600	213,100	220,500	225,200
Taxes	16,900	17,300	17,700	16,700	42,600	44,100	45,100
Freight	28,100	28,900	29,500	27,800	71,000	73,500	75,100
Total purchased cost	691,700	711,100	725,500	684,700	1,747,200	1,807,800	1,847,000
2. Installation Direct Costs	622,500	640,000	652,900	616,200	1,572,500	1,627,000	1,662,300
TOTAL DIRECT COSTS (1 + 2)	1,314,200	1,351,100	1,378,400	1,300,900	3,319,700	3,434,800	3,509,300
INDIRECT COSTS							
3. Installation Indirect Costs	415,000	426,700	435,300	410,800	1,048,200	1,084,700	1,108,200
TOTAL CAPITAL COST (1 + 2 + 3)	1,729,200	1,777,800	1,813,700	1,711,700	4,367,900	4,519,500	4,617,500

(continued)

TABLE 8-5. (continued)

Cost element	Furnace type[a] Capture equipment[b] Model plant[c] Regulatory alternative[e]	C 1 3[d] 1	C 2 3 2	C 3 3 3	D 1 4[d] 1	D 2 4 2	D 3 4 3
DIRECT COSTS							
1. Purchased Equipment Costs							
A. Primary							
Fabric filter		752,800	752,800	825,200	957,900	957,900	970,100
B. Auxiliary							
Canopy hood with dampers		46,450	64,500	64,500	39,650	51,200	51,200
DEC water-cooled duct (100 ft)		117,100	117,100	117,100	217,400	217,400	217,400
Total furnace enclosure		--	--	--	--	--	--
Scavenger duct with partitions		--	91,800	91,800	--	64,900	64,900
Dust handling[f]		67,800	67,800	67,800	67,800	67,800	67,800
Continuous opacity monitor		9,750	--	--	9,750	--	--
Continuous flow monitoring		4,900	--	--	4,900	--	--
Fan system		369,600	369,600	410,700	492,900	492,900	533,900
Ductwork (250 ft)		188,000	188,000	203,400	222,200	222,200	229,100
Emergency air dilution damper		28,600	28,600	31,100	34,200	34,200	35,300
Total (A + B)		1,585,000	1,680,200	1,811,600	2,046,700	2,108,500	2,169,700
Instruments and controls		237,700	252,000	271,700	307,000	316,300	325,500
Taxes		47,500	50,400	54,400	61,400	63,300	65,100
Freight		79,300	84,000	90,600	102,300	105,400	108,500
Total purchased cost		1,949,500	2,066,600	2,228,300	2,517,400	2,593,500	2,668,800
2. Installation Direct Costs		1,754,600	1,859,900	2,005,500	2,265,600	2,334,200	2,401,900
TOTAL DIRECT COSTS (1 + 2)		3,704,100	3,926,500	4,233,800	4,783,000	4,927,700	5,070,700
INDIRECT COSTS							
3. Installation Indirect Costs		1,169,700	1,240,000	1,337,000	1,510,400	1,556,100	1,601,300
TOTAL CAPITAL COST (1 + 2 + 3)		4,873,800	5,166,500	5,570,800	6,293,400	6,483,800	6,672,000

[a] From Table A-1.

[b] 1 = DEC, canopy hood, open roof.
2 = DEC, segmented canopy hood, scavenger duct with partitions, open/closed roof.
3 = DEC, segmented canopy hood, scavenger duct with partitions, closed roof.
4 = TFE, canopy hood, closed roof.

[c] From Table 1.

[d] Existing facilities.

[e] From Table 3.

[f] Includes screw conveyor, pneumatic dust conveying system, and dust storage silo.

TABLE 8-6. CAPITAL COSTS FOR FABRIC FILTER CONTROL METHOD--NEW SPECIALTY STEEL FACILITIES[10] (March 1981 Dollars)

Cost element	Furnace type[a] Capture equipment[b] Model plant[c] Reg. alt.[e]	A 4 8[d] 1	A 5 8 2	A 6 8 3	B 4 9[d] 1	B 5 9 2	B 6 9 3	E 1 8[d] 1	E 2 8 2	E 3 8 3
DIRECT COSTS										
1. Purchased Equipment Costs										
A. Primary										
Fabric filter		266,300	266,300	275,500	646,800	646,800	673,800	309,200	309,200	328,900
B. Auxiliary										
Canopy hood with dampers		13,150	18,000	17,700	30,750	41,200	40,200	12,900	13,300	13,300
DEC water-cooled duct (100 ft)		73,600	73,600	73,600	162,100	162,100	162,100	--	--	--
Close-fitting hood and duct		--	--	--	--	--	--	31,800	31,800	31,800
Continuous opacity monitor		9,750	--	--	9,750	--	--	--	--	--
Scavenger duct with partitions		--	14,800	14,800	--	29,400	29,400	--	14,800	14,800
Continuous flow monitoring		4,900	--	--	4,900	--	--	--	--	--
Dust handling[f]		22,900	22,900	22,900	41,600	41,600	41,600	22,900	22,900	22,900
Fan system		82,100	82,100	82,100	328,600	328,600	328,600	144,900	144,900	144,900
Ductwork (250 ft)		72,400	72,400	74,700	166,800	166,800	171,900	81,000	81,000	84,800
Emergency air dilution damper		9,900	9,900	10,300	25,000	25,000	25,800	11,300	11,300	11,800
Total (A + B)		555,000	560,000	571,600	1,416,300	1,441,500	1,473,400	614,000	629,200	653,200
Instruments and controls		83,300	84,000	85,700	212,400	216,200	221,000	92,100	94,400	98,000
Taxes		16,600	16,800	17,200	42,500	43,200	44,200	18,400	18,900	19,600
Freight		27,800	28,000	28,600	70,800	72,100	73,700	30,700	31,500	32,700
Total purchased cost		682,700	688,800	703,100	1,742,000	1,773,000	1,812,300	755,200	774,000	803,500
2. Installation Direct Costs		614,400	619,900	632,800	1,567,800	1,595,700	1,631,100	679,600	696,600	723,200
TOTAL DIRECT COSTS (1 + 2)		1,297,100	1,308,700	1,335,900	3,309,800	3,368,700	3,443,400	1,434,800	1,470,600	1,526,700
INDIRECT COSTS										
3. Installation Indirect Costs		409,600	413,300	421,900	1,045,200	1,063,800	1,087,400	453,100	464,400	482,100
TOTAL CAPITAL COST (1 + 2 + 3)		1,706,700	1,722,000	1,757,800	4,355,000	4,432,500	4,530,800	1,887,900	1,935,000	2,008,800

(continued)

TABLE 8-6. (continued)

Cost element	Furnace type[a] Capture equipment[b] Model plant[c] Reg. alt.[e]	F 1 9[d] 1	F 2 9 2	F 3 9 3	A/E 4,1 8[d] 1	A/E 5,2 8 2	A/E 6,3 8 3	B/F 4,1 9[d] 1	B/F 5,2 9 2	B/F 6,3 9 3
DIRECT COSTS										
1. Purchased Equipment Costs										
A. Primary										
Fabric filter		809,600	809,600	873,800	434,200	434,200	451,800	1,311,500	1,311,500	1,386,500
B. Auxiliary										
Canopy hood with dampers		30,700	30,700	30,700	26,050	31,300	31,000	61,000	71,900	70,900
DEC water-cooled duct (100 ft)		--	--	--	73,600	73,600	73,600	162,100	162,100	162,100
Close-fitting hood and duct		90,400	90,400	90,400	31,800	31,800	31,800	90,400	90,400	90,400
Continuous opacity monitor		--	--	--	9,750	--	--	19,500	--	--
Scavenger duct with partitions		--	29,400	29,400	--	29,600	29,600	--	58,800	58,800
Continuous flow monitoring		--	--	--	4,900	--	--	4,900	--	--
Dust handling[f]		41,600	41,600	41,600	45,800	45,800	45,800	76,900	76,900	76,900
Fan system		410,700	410,700	410,700	164,300	164,300	164,300	698,200	698,200	739,300
Ductwork (250 ft)		189,900	189,900	199,900	116,200	116,200	120,300	280,200	280,200	293,200
Emergency air dilution damper		28,900	28,900	30,600	16,900	16,900	17,500	43,100	43,100	45,000
Total (A + B)		1,601,400	1,631,200	1,707,100	923,500	943,700	965,700	2,747,800	2,793,100	2,923,100
Instruments and controls		240,200	244,700	256,100	138,500	141,600	144,900	412,200	419,000	438,500
Taxes		48,000	48,900	51,200	27,700	28,300	29,000	82,400	83,800	87,700
Freight		80,100	81,600	85,400	46,200	47,200	48,300	137,400	139,700	146,200
Total purchased cost		1,969,700	2,006,400	2,099,800	1,135,900	1,160,800	1,187,900	3,379,800	3,435,600	3,595,500
2. Installation Direct Costs		1,772,800	1,805,800	1,889,800	1,022,300	1,044,700	1,069,100	3,041,800	3,092,000	3,235,900
TOTAL DIRECT COSTS (1 + 2)		3,742,500	3,812,200	3,989,600	2,158,200	2,205,500	2,257,000	6,421,600	6,527,600	6,831,400
INDIRECT COSTS										
3. Installation Indirect Costs		1,181,800	1,203,800	1,259,900	681,500	696,500	712,700	2,027,800	2,061,400	2,157,300
TOTAL CAPITAL COST (1 + 2 + 3)		4,924,300	5,016,000	5,249,500	2,839,700	2,902,000	2,969,700	8,449,400	8,589,000	8,988,700

[a] From Table A-1.

[b] 1 = Close-fitting hood, canopy hood, open roof.
2 = Close-fitting hood, canopy hood, scavenger duct with partitions, open/closed roof.
3 = Close-fitting hood, canopy hood, scavenger duct with partitions, closed roof.
4 = DEC, canopy hood, open roof.
5 = DEC, segmented canopy hood, scavenger duct with partitions, open/closed roof.
6 = DEC, segmented canopy hood, scavenger duct with partitions, closed roof.

[c] From Table 1.

[d] Existing furnaces/vessels.

[e] From Tables 3 and 4.

[f] Includes screw conveyor, pneumatic dust conveying system, and dust storage silo.

EAF dust is considered hazardous, and disposal at a certified landfill is required. Tables 8-7 and 8-8 present a detailed cost breakdown of the annualized costs for fabric filter control systems at carbon and specialty steel plants, respectively. The annualized costs under Regulatory Alternatives 2 and 3 are higher than those costs under Regulatory Alternative 1 even though the costs for periodic monitoring are less than costs for continuous monitoring.

The total EAF capacity growth projection from 1983 to 1987 is estimated to be 5.2 $\times 10^6$ Mg (5.73 $\times 10^6$ tons) (Chapter 7). This constitutes a 4.8 $\times 10^6$-Mg (5.29 $\times 10^6$-ton) increase in capacity in carbon steel shops and a 0.4 $\times 10^6$-Mg (0.44 $\times 10^6$-ton) increase in capacity in specialty steel shops. The estimated distribution of the number of plants in the various size capacities to satisfy the growth projections are listed in Table 8-9 along with the control system capital and annualized costs at various regulatory alternatives. As shown, the carbon steel industry would need to spend up to $82 million in capital costs to install control systems by 1987 to meet the regulatory alternatives and up to $29 million in annual operating and maintenance costs in 1987. The baseline costs would be about $76.2 million in capital costs and about $27.4 million in annual operating and maintenance costs.

The specialty steel industry would need to spend up to $24 million in control equipment capital costs by 1987 and about $6.7 million in annual operating and maintenance costs in 1987 to meet the projected capacity growth. The baseline costs would be about $22.6 million in capital costs and about $6.3 million in annual operating and maintenance costs.

8.1.1 New Facilities

Costs for the air pollution control systems for the new facilities are based on the model plant and the capture/control system design parameters presented in Chapter 6. These costs were derived from the cost factors developed for purchase and installation expenditures.[7] The Chemical Engineering Plant Cost Index was used to adjust costs given in Reference 7.

Table 8-10 presents the annual costs of incremental (over baseline levels) collection of process and fugitive dust. Total furnace enclosures are evaluated as a process and fugitive emissions capture system option

TABLE 8-7. ANNUALIZED COSTS FOR FABRIC FILTER CONTROL METHOD--NEW CARBON STEEL FACILITIES[10]
(March 1981 Dollars)

Cost element							
Furnace type[a]	A	A	A	A	B	B	B
Capture equipment[b]	1	2	3	4	1	2	3
Model plant[c]	1[d]	1	1	1	2[d]	2	2
Regulatory alternative[e]	1	2	3	3	1	2	3
DIRECT OPERATING COSTS							
1. Utilities							
A. Electricity	65,200	65,200	70,200	57,700	314,600	314,600	314,600
2. Operating labor							
A. Direct labor	16,731	16,731	16,731	16,731	18,252	18,252	18,252
B. Supervision	2,510	2,510	2,510	2,510	2,738	2,738	2,738
3. Maintenance							
A. Labor	6,132	6,132	6,132	6,132	6,690	6,690	6,690
B. Materials	6,132	6,132	6,132	6,132	6,690	6,690	6,690
4. VE observer	--	4,540	4,540	4,540	--	4,540	4,540
5. Flow monitoring	25,000	13,600	13,600	13,600	25,000	13,600	13,600
6. Replacement parts							
A. Bags for fabric filters	7,733	7,733	8,467	5,800	29,000	29,000	30,800
B. Filters for opacity monitors	130	--	--	--	130	--	--
7. Solid waste transfer	54,407	54,965	55,242	55,242	237,411	239,841	241,055
INDIRECT OPERATING COSTS							
8. Overhead	20,300	20,300	20,300	20,300	22,144	22,144	22,144
9. Capital charges							
A. Administration	34,284	35,556	36,274	34,234	87,058	90,390	92,350
B. Property tax	17,142	17,778	18,137	17,117	43,529	45,195	46,175
C. Insurance	17,142	17,778	18,137	17,117	43,529	45,195	46,175
D. Capital recovery cost	227,992	233,780	238,501	225,088	574,978	594,314	607,201
TOTAL ANNUALIZED COSTS	500,835	502,735	514,903	482,243	1,411,749	1,433,190	1,453,010

(continued)

TABLE 8-7. (continued)

Cost element	Furnace type[a] Capture equipment[b] Model plant[c] Regulatory alternative[e]	C 1 3[d] 1	C 2 3 2	C 3 3 3	D 1 4[d] 1	D 2 4 2	D 3 4 3
DIRECT OPERATING COSTS							
1. Utilities							
A. Electricity		399,400	399,400	479,300	466,100	466,100	485,600
2. Operating labor							
A. Direct labor		22,206	22,206	22,206	21,600	21,600	21,600
B. Supervision		3,330	3,330	3,330	3,240	3,240	3,240
3. Maintenance							
A. Labor		8,140	8,140	8,140	7,916	7,916	7,916
B. Materials		8,140	8,140	8,140	7,916	7,916	7,916
4. VE observer		--	4,540	4,540	--	4,540	4,540
5. Flow monitoring		25,000	13,600	13,600	25,000	13,600	13,600
6. Replacement parts							
A. Bags for fabric filters		34,800	34,800	39,867	47,267	47,267	47,267
B. Filters for opacity monitors		130	--	--	130	--	--
7. Solid waste transfer		866,550	875,420	879,855	632,173	638,643	641,880
INDIRECT OPERATING COSTS							
8. Overhead		26,940	26,940	26,940	26,205	26,205	26,205
9. Capital charges							
A. Administration		97,176	103,330	111,416	125,568	129,676	133,440
B. Property tax		48,588	51,665	55,708	62,784	64,838	66,720
C. Insurance		48,588	51,665	55,708	62,784	64,838	66,720
D. Capital recovery cost		641,504	679,395	732,560	828,182	852,620	877,368
TOTAL ANNUALIZED COSTS		2,230,492	2,282,570	2,441,310	2,316,865	2,348,998	2,404,010

[a] From Table A-1.

[b] 1 = DEC, canopy hood, open roof.
2 = DEC, segmented canopy hood, scavenger duct with partitions, open/closed roof.
3 = DEC, segmented canopy hood, closed roof, scavenger duct with partitions.
4 = TFE, canopy hood, closed roof.

[c] From Table 1.

[d] Existing furnace.

[e] From Table 3.

TABLE 8-8. ANNUALIZED COSTS FOR FABRIC FILTER CONTROL METHOD--NEW SPECIALTY STEEL FACILITIES[10]
(March 1981 Dollars)

Furnace type[a]	A	A	A	B	B	B	E	E	E
Capture equipment[b]	4	5	6	4	5	6	1	2	3
Model plant[c]	8[d]	8	8	9[d]	9	9	8[d]	8	8
Cost element Reg. alt.[e]	1	2	3	1	2	3	1	2	3
DIRECT OPERATING COSTS									
1. Utilities									
A. Electricity	65,200	65,200	70,200	314,600	314,600	314,600	105,300	105,300	112,800
2. Operating labor									
A. Direct labor	16,731	16,731	16,731	18,252	18,252	18,252	16,731	16,731	16,731
B. Supervision	2,510	2,510	2,510	2,738	2,738	2,738	2,510	2,510	2,510
3. Maintenance									
A. Labor	6,132	6,132	6,132	6,690	6,690	6,690	6,132	6,132	6,132
B. Materials	6,132	6,132	6,132	6,690	6,690	6,690	6,132	6,132	6,132
4. VE observer	--	4,540	4,540	--	4,540	4,540	--	4,540	4,540
5. Flow monitoring	25,000	13,600	13,600	25,000	13,600	13,600	--	13,600	13,600
6. Replacement parts									
A. Bags for fabric filters	7,733	7,733	8,467	29,000	29,000	30,800	10,267	10,267	11,600
B. Filters for opacity monitor	130	--	--	130	--	--	--	--	--
7. Solid waste transfer[f]	--	--	--	--	--	--	--	--	--
INDIRECT OPERATING COSTS									
8. Overhead	20,300	20,300	20,300	22,144	22,144	22,144	20,300	20,300	20,300
9. Capital charges									
A. Administration	33,828	34,440	35,156	86,800	88,650	90,616	37,758	38,700	40,176
B. Property tax	16,914	17,220	17,578	43,400	44,325	45,308	18,879	19,350	20,088
C. Insurance	16,914	17,220	17,578	43,400	44,325	45,308	18,879	19,350	20,088
D. Capital recovery cost	224,991	226,443	231,150	573,282	582,873	595,800	248,259	254,452	264,157
TOTAL ANNUALIZED COSTS	442,515	438,200	450,075	1,172,126	1,178,428	1,197,085	491,147	517,365	538,854

(continued)

TABLE 8-8. (continued)

Cost element / Furnace type[a] / Capture equipment[b] / Model plant[c] / Reg. alt.[e]	F 1 9[d] 1	F 2 9 2	F 3 9 3	A/E 4,1 8[d] 1	A/E 5,2 8 2	A/E 6,3 8 3	B/F 4,1 9[d] 1	B/F 5,2 9 2	B/F 6,3 9 3
DIRECT OPERATING COSTS									
1. Utilities									
A. Electricity	393,900	393,900	410,300	210,600	210,600	220,700	755,000	755,000	771,400
2. Operating labor									
A. Direct labor	18,252	18,252	18,252	16,731	16,731	16,731	18,252	18,252	18,252
B. Supervision	2,738	2,738	2,738	2,510	2,510	2,510	2,738	2,738	2,738
3. Maintenance									
A. Labor	6,690	6,690	6,690	12,264	12,264	12,264	13,380	13,380	13,380
B. Materials	6,690	6,690	6,690	12,264	12,264	12,264	13,380	13,380	13,380
4. VE observer	--	4,540	4,540	--	4,540	4,540	--	5,740	5,740
5. Flow monitoring	--	13,600	13,600	25,000	13,600	13,600	25,000	13,600	13,600
6 Replacement parts									
A. Bags for fabric filters	38,667	38,667	42,533	17,667	17,667	18,133	67,133	67,133	72,133
B. Filters for opacity monitor	--	--	--	130	--	--	260	--	--
7. Solid waste transfer[f]	--	--	--	--	--	--	--	--	--
INDIRECT OPERATING COSTS									
8. Overhead	22,144	22,144	22,144	25,204	25,204	25,204	27,496	27,496	27,496
9. Capital charges									
A. Administration	98,486	100,320	104,990	56,494	58,040	59,394	168,688	171,780	179,774
B. Property tax	49,243	50,160	52,495	28,247	29,020	29,697	84,344	85,890	89,887
C. Insurance	49,243	50,160	52,495	28,247	29,020	29,697	84,344	85,890	89,887
D. Capital recovery cost	647,545	659,604	690,309	374,020	381,613	390,515	1,111,696	1,129,453	1,182,014
TOTAL ANNUALIZED COSTS	1,333,598	1,367,465	1,427,776	809,378	813,073	835,250	2,371,711	2,389,732	2,479,680

[a] From Table A-1.

[b] 1 = Close-fitting hood, canopy hood, open roof.
2 = Close-fitting hood, canopy hood, scavenger duct with partitions, open/closed roof.
3 = Close-fitting hood, canopy hood, scavenger duct with partitions, closed roof.
4 = DEC, canopy hood, open roof.
5 = DEC, segmented canopy hood, scavenger duct with partitions, open/closed roof.
6 = DEC, segmented canopy hood, scavenger duct with partitions, closed roof.

[c] From Table 1.

[d] Existing furnaces/vessels.

[e] From Tables 3 and 4.

[f] Solid waste disposal costs are not incurred since the dust is processed to reclaim Cr, Ni, and Fe.

TABLE 8-9. PROJECTED NATIONWIDE CONTROL SYSTEM EXPENDITURES UNDER VARIOUS REGULATORY ALTERNATIVES (BY 1987)
(March 1981 dollars)

		Capital costs, $\$10^6$			Annualized costs, $\$10^6$		
		Regulatory alternative			Regulatory alternative		
Model plants	No. of plants	1	2	3	1	2	3
Carbon Steel							
One 90.7-Mg (100-ton) EAF	8	35.0	36.2	37.0	11.3	11.5	11.6
One 136.1-Mg (150-ton) EAF	5	31.5	32.4	33.4	11.6	11.7	12.0
One 272.2-Mg (300-ton) EAF	2	9.7	10.3	11.1	4.5	4.6	4.9
Total	15	76.2	78.9	81.5	27.4	27.8	28.5
Specialty Steel							
One 22.7-Mg (25-ton) EAF/AOD shop	2	5.7	5.8	5.9	1.6	1.6	1.7
One 90.7-Mg (100-ton) EAF/AOD shop	2	16.9	17.2	18.0	4.7	4.8	5.0
Total	4	22.6	23.0	23.9	6.3	6.4	6.7

TABLE 8-10. AVERAGE COST EFFECTIVENESS OF EAF/AOD PROCESS AND FUGITIVE EMISSIONS CONTROL OVER BASELINE

Model plant	Regulatory alternative	Emission reduction over baseline		Incremental cost over baseline	Annual cost of incremental collection[a]	
		Mg/yr	tons/yr	$/yr	$/Mg	$/ton
1. New shop: one 22.7-Mg (25-ton) EAF	1	0	0	0	0	0
	2	6.1	6.7	1,900	311	284
	3	12.3	13.5	14,100	1,146	1,044
	3[b]	12.3	13.5	-18,600	-1,512	-1,377
2. New shop: one 90.7-Mg (100-ton) EAF	1	0	0	0	0	0
	2	26.7	29.4	21,500	805	731
	3	53.3	58.8	41,300	775	702
3. New shop: one 272.2-Mg (300-ton) EAF	1	0	0	0	0	0
	2	97.2	107.1	52,100	536	486
	3	194.6	214.5	210,800	1,083	983
4. New shop: one 136.1-Mg (150-ton) UHP EAF	1	0	0	0	0	0
	2	70.9	78.1	32,100	453	411
	3	142.0	156.5	87,100	613	556
5. One new 272.2-Mg (300-ton) EAF added to an existing shop	1	0	0	0	0	0
	2	97.2	107.1	53,900	554	503
	3	194.6	214.5	218,000	1,120	1,016
6. One new 22.7-Mg (25-ton) EAF added to an existing shop	1	0	0	0	0	0
	2	6.1	6.7	1,900	311	284
	3	12.3	13.5	14,600	1,187	1,081
	3[b]	12.3	13.5	-19,300	-1,569	-1,430
7. New shop: EAF and AOD vessel, 22.7-Mg (25-ton) capacity each; controlled separately	1	0	0	0	0	0
	2	9.3	10.2	21,900	2,355	2,147
	3	18.7	20.6	55,300	2,957	2,684
8. New shop: EAF and AOD vessel, 22.7-Mg (25-ton) capacity each; controlled in common	1	0	0	0	0	0
	2	9.3	10.2	3,700	398	363
	3	18.7	20.6	25,900	1,395	1,257
9. New shop: EAF and AOD 90.7-Mg (100-ton) capacity each; separately controlled	1	0	0	0	0	0
	2	40.6	44.7	40,100	988	897
	3	81.5	89.8	119,100	1,461	1,326
10. New shop: EAF and AOD vessel, 90.7-Mg (100-ton) capacity each; controlled in common	1	0	0	0	0	0
	2	40.6	44.7	18,000	443	403
	3	81.5	89.8	108,000	1,325	1,203

[a] Costs are per megagram (ton) of particulate matter removed.

[b] Total furnace enclosure option.

under Regulatory Alternative 3 for smaller furnaces. This is because TFE's have been used primarily on smaller furnaces, and there is very limited operating experience related to TFE's used on medium-to-large furnaces. As shown on Table 8-10, the TFE capture system incremental cost is negative, which means that better capture of fugitive emissions (over baseline levels) is achieved at a lower cost. Total furnace enclosures require lower air flow rates than other comparable capture systems to achieve similar efficiencies, thus resulting in lower costs. The incremental costs of collecting dust are higher for the smaller furnaces. The smaller furnace/higner cost relationship is also true with the AOD vessels.

The annual cost under Regulatory Alternatives 2 and 3 ranges from a high of $1,146/Mg (1,044/ton) to a low of $311/Mg ($284/ton) of emission reduction for new EAF facilities. The range is from a high of $2,957/Mg ($2,684/ton) to a low of $398/Mg ($363/ton) of emission reduction for new specialty steel facilities with an EAF and AOD vessel.

The capital and annualized costs for retrofit facilities are also presented in Tables 8-1 and 8-4. The control system capital costs for the retrofit facilities are about 20 percent higher than those which would be incurred in a greenfield plant. At the same time, the capital cost for the retrofit plant is estimated to be about 75 percent of the cost of a greenfield plant, taking into consideration the existing building and availability of some of the auxiliary equipment, such as cranes, charge buckets, ladles, casting capabilities, etc.[3] Thereby, the percentage of the control system capital costs compared to the total plant capital costs are higher.

8.1.2 Modified/Reconstructed Facilities

The capital costs for modifying a 136.1-Mg (150-ton) EAF from normal power to ultra high power (UHP) are estimated to be between 25 and 30 percent of those for a new greenfield plant.[4] Thus, the costs incurred in the modification of the furnace may range between $8.3 million and $10 million.

The capital cost for upgrading the control system to meet the level of emission reduction required by the standards of performance is estimated to be about 20 percent of the cost for a new control system. This would result in an expenditure of about $1.3 million.

8.2 OTHER COST CONSIDERATIONS

In addition to the cost of control for process and fugitive emissions, there are other regulatory costs mandated under the Occupational Safety and Health Act (OSHA) and the Resource Conservation and Recovery Act (RCRA).

The Office of Technology Assessment estimates that investment costs to comply with OSHA are about 14 percent of costs to comply with standards of performance on an industry wide basis. Applying this percentage to EAF/AOD pollution control systems gives the results presented in Table 8-11.

The EAF dust is classified as hazardous under RCRA. The annualized costs for the control systems shown in Table 8-4 include the solid waste handling system costs and the solid waste disposal costs. The incremental costs are not significantly increased because the EAF dust is already being handled as a hazardous material. As explained in Chapter 7, research is being conducted to develop ways of recycling the EAF dust to help reduce or eliminate the hazardous waste material disposal costs.

The collected dust from EAF/AOD combined operations and control may be processed at a reclamation center. Therefore, no solid waste disposal costs are included in the calculation of annualized costs for the specialty steel shops.[10]

There are no costs related to water pollution control resulting from the use of the air pollution control systems on either EAF's or AOD vessels.

Promulgation of standards of performance for EAF's and AOD vessels is not expected to impose major resource requirements on regulatory and enforcement agencies since the agencies are already maintaining surveillance for the sources in the EAF/AOD shops for primary emission control.

TABLE 8-11. COST ESTIMATES FOR OSHA COMPLIANCE--EAF/AOD VESSEL FACILITIES[13] (March 1981 dollars)

Model plant	Regulatory alternative	Total pollution control investment $\$10^6$	OSHA compliance investment[a] $\$10^3$
1. New shop: one 22.7-Mg (25-ton) EAF	1	1.73	242
	2	1.78	249
	3	1.81	253
	3[b]	1.71	239
2. New shop: one 90.7-Mg (100-ton) EAF	1	4.37	612
	2	4.52	633
	3	4.62	647
3. New shop: one 272.2-Mg (300-ton) EAF	1	4.87	682
	2	5.17	724
	3	5.57	780
4. New shop: one 136.1-Mg (150-ton) UHP EAF	1	6.29	881
	2	6.48	907
	3	6.67	934
5. One new 272.2-Mg (300-ton) EAF added to an existing shop	1	5.84	818
	2	6.20	868
	3	6.68	935
6. One new 22.7-Mg (25-ton) EAF added to an existing shop	1	2.08	291
	2	2.14	300
	3	2.17	304
	3[b]	2.05	287
7. New shop: EAF and AOD vessel, 22.7-Mg (25-ton) capacity each; controlled separately	1	3.59	503
	2	3.65	511
	3	3.77	528
8. New shop: EAF and AOD vessel, 22.7-Mg (25-ton) capacity each; commonly controlled	1	2.84	398
	2	2.90	406
	3	2.97	416
9. New shop: EAF and AOD 90.7-Mg (100-ton) capacity each; separately controlled	1	9.28	1,299
	2	9.45	1,323
	3	9.78	1,369
10. New shop: EAF and AOD vessel 90.7-Mg (100-ton) capacity each; commonly controlled	1	8.45	1,183
	2	8.59	1,203
	3	8.99	1,259

[a] Calculated as 14 percent of total pollution control investment.
[b] Total furnace enclosure option.

8.3 REFERENCES FOR CHAPTER 8

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3. Letter and attachments from Lukas, A., Jones & Laughlin Steel Corp., to Banker, L., Midwest Research Institute. February 17, 1981. Submittal of requested information.

4. Telecon. Banker, L., Midwest Research Institute, with Nicholson, W., Chaparral Steel Corp. August 26, 1981. Information on furnace modifications and installation of a new furnace.

5. Telecon. Terry, W., Midwest Research Institute, with Baker, D., Rockwood Iron & Metal Co. August 24, 1981. Information on retrofitting emission controls on Rockwood Iron's facility.

6. Producer Prices and Price Indexes. U.S. Department of Labor, Bureau of Labor Statistics. Data for March 1981.

7. Capital and Operating Costs of Selected Air Pollution Control Systems. GARD, Inc. Niles, Illinois. EPA No. 450/5-80-002. December 1978.

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9. Memo from Pahl, D., EPA:SDB, to the files. March 31, 1980. Basis for estimation of hazardous waste hauling and disposal costs.

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9. ECONOMIC IMPACTS

9.1 SUMMARY OF IMPACTS

Three regulatory alternatives proposed for electric arc furnace (EAF) and electric arc furnace/argon-oxygen decarburization (EAF/AOD) steel plants are considered in this analysis. Regulatory alternative 1 is the baseline alternative from which the impacts of the more stringent alternatives 2 and 3 are measured. Several impacts are computed for each alternative; one for each of the 10 model plants. In an effort to provide a more useful analysis, a single impact estimate is presented for each alternative based on the premise that model plants 4 and 7 are most representative of future plant construction. Impacts are computed for 1987 in 1981 dollars.

As noted, regulatory alternative 1 is the baseline from which the impacts of alternatives 2 and 3 are computed. It is projected that in 1987, at baseline, domestic semifinished steel output would be 119.7 million Mg (131.7 million tons); steel industry employment would be 438,461 workers; and steel consumers in the U.S. would import 20.3 million Mg (22.3 million tons) of foreign steel.

It is estimated that the price of semifinished carbon steel would be $0.12 per Mg ($0.11 per ton) higher in 1987 under alternative 2 than it would be under baseline alternative 1. The impact on the price of specialty steel is an estimated $0.81 per Mg ($0.74 per ton) increase. These price increases represent impacts of 0.06 percent and 0.12 percent respectively.

Steel users could purchase less domestic steel and more foreign steel in 1987 as a result of the increases in domestic steel prices. Domestic steel shipments would be down an estimated 150,000 Mg (165,000 tons) from baseline under alternative 2--an impact of 0.13 percent. Imports could be approximately 19,000 Mg (21,000 tons) greater--an impact of 0.09 percent.

The impact on domestic steel production would cause an estimated reduction in employment opportunities of about 0.12 percent, or about 542 jobs, in 1987. The estimated total cost of regulatory alternative 2 in 1987 is $1.381 million (in 1981 dollars).

It is estimated that regulatory alternative 3 would raise the price of semifinished carbon steel by $0.30 per Mg ($.27 per ton) above its baseline 1987 price. The anticipated impact on the price of specialty steel of alternative 3 is $2.09 per Mg ($1.90 per ton). These price increases represent impacts of 0.15 percent and 0.31 percent respectively.

Domestic steel shipments would be down an estimated 370,000 Mg (407,000 tons) in 1987 under regulatory alternative 3--an impact of 0.31 percent. This impact on domestic steel production would cause a proportionate decrease in 1987 employment opportunities, about 1,387 jobs. Steel imports in 1987 would be approximately 40,000 Mg (44,000 tons) higher under alternative 3 than under baseline control--an impact of 0.20 percent. The estimated total cost of alternative 3 in 1987 is $2.575 million (in 1981 dollars).

Electric arc steel making is apparently a profitable activity. This is indicated by two kinds of evidence. First, construction of new EAF facilities and the replacement of older steel making technologies by EAF shops is brisk. This indicates that the industry itself views EAF steel making as profitable. Second, the engineering cost data for the 10 model facilities examined in this study suggest strongly that steel can be produced at an average total cost significantly below market price. In light of this observation, it seems unlikely that the industry impacts reported above would significantly affect the future growth of electric steel making.

9.2 INDUSTRY PROFILE

9.2.1 Introduction

This industry profile focuses on the blast furnaces and steel mills industry. The profile has two purposes. The first is informative in nature; the profile should provide the reader with a broad overview of the industry. In this sense, the industry profile should be meaningful when read alone. The second purpose is to lend support to an economic analysis involving the industry by helping to assess the appropriateness of using a competitive, monopoly, or other model to analyze the industry. Further, the profile can provide some of the necessary data that will be used in the analysis itself.

The industry profile is comprised of five major sections. The remainder of this introduction, which constitutes the first section, provides a brief, descriptive, and largely qualitative look at the industry. The remaining four sections of the profile conform with a particular model of industrial organization analysis. This model maintains that an industry can be characterized by its basic conditions (supply and demand), market structure, market conduct, and market performance.[1]

The basic conditions in the industry, discussed in the second major section of this profile, are believed to be a major determinant of the prevailing market structure. Most important of these basic conditions are supply and demand conditions. Supply conditions are largely technological in nature, while demand conditions are determined by the attributes of the products themselves.

The market structure of the blast furnaces and steel mills industry is examined in the third section of this profile. Issues addressed include economic aspects of production functions, cost structures, market power, integration, and barriers to entry. Market structure is the second link in the overall framework, and has major influence on the third link, the conduct of market participants.

Market conduct, addressed in the fourth section, concerns price and nonprice behavior of sellers. Of particular interest is the degree to which the industry pricing behavior approximates the competitive pricing model, the monopoly pricing model, or some model of imperfect competition.

The fifth and final section of the industry profile addresses market performance. The historical record of the industry's financial performance is examined, with some emphasis on its comparison with other industries. Industry trends are noted, and projections are presented for key variables such as price, output, and investment.

9.2.1.1 Definition of the Blast Furnaces and Steel Mills Industry. The blast furnaces and steel mills industry (hereafter the steel industry) is the name given to those firms classified in SIC 3312. The industry comprises establishments primarily engaged in the production of hot metal, pig iron, and ferroalloys from iron ore and iron and steel scrap. SIC 3312 also includes establishments that produce coke, an important fuel input to iron production. Establishments primarily engaged in converting pig iron, scrap iron, and scrap steel into steel are also classified in SIC 3312. Finally, SIC 3312 includes establishments primarily engaged in hot rolling iron and steel into such basic products as plates, sheets, bars, and tubing.[2]

The majority of all goods produced by plants in the steel industry are intermediate in nature. As such, they are generally shipped to other plants within SIC 3312 or to plants classified in other industries to be used as inputs in the production of final goods or other intermediate goods. The input-output relationships of SIC 3312 will be dealt with in detail in Section 9.1.2. It is worthwhile to note here that the demand for blast furnace and steel mill products depends only indirectly upon consumer tastes and preferences. It will be shown later that this indirect link is nonetheless significant.

9.2.1.2 The Steel Industry in the Macroeconomy. The value added by all establishments in SIC 3312 in 1977 was $15,331.9 million. This represents approximately 0.8 percent of total gross national product for 1977. Employment in the steel industry in 1977 was 441,900, approximately 0.5 percent of total U.S. employment in 1977. Capital expenditures on new plant and equipment in SIC 3312 was $2,143.1 million in 1977, approximately 0.7 percent of the national total.[3] [4]

A comparison of these shares to those of other industries provides a greater understanding of the importance of SIC 3312 in the overall economy. The $15,331.9 million of value added by the steel industry in 1977 was approximately 6.3 percent greater than that of SIC 2911, the petroleum refining industry. Value added by the motor vehicle industry--SIC 3711 in 1977 was approximately 22 percent greater than that of the steel industry.[5] SIC 3312 is thus seen to be among the larger manufacturing industries.

The U.S. steel industry is a major contributor to total world steel production. In 1979, the world leader in steel production was the Soviet Union, which produced 19.9 percent of worldwide steel output. The United States was second, with 16.5 percent of total world production. Japan produced 14.9 percent of total steel produced in 1977.[6]

9.2.2 Basic Conditions

9.2.2.1 Supply Conditions.

9.2.2.1.1 Product description. Nearly all output of SIC 3312 consists of intermediate goods. As such, most steel mill products are sold to producers of other goods. These goods, in turn, might be final goods such as automobiles, or other intermediate goods such as engine pistons and valves.

Sales of these intermediate goods can be classified into three types. The first type consists of sales of the intermediate goods from plants classified in SIC 3312 to plants classified in other SIC codes. In 1972, approximately 83 percent of all sales from SIC 3312 were of this type.[7] The second type of sale involves shipments from plants classified in SIC 3312 to other plants classified in the same industry. The third type of sale is actually implicit in nature and is represented by the transfer of goods within a plant from one production stage to another. These two types of intraindustry sales together accounted for approximately 17 percent of all SIC 3312 sales in 1972.[7]

A large number of identifiably distinct products is produced by plants classified in SIC 3312. It is useful to categorize SIC 3312 output into four products: coke, pig iron, raw steel, and finished steel products.

Coke is the carbon residue that results from the heating of coal in the absence of oxygen. Coke constitutes the chief fuel used in blast furnaces to produce pig iron from iron ore. Coke is classified as a steel industry product since it is nearly always produced as a secondary product in SIC 3312 plants. While certain other fuels may be used to supplement coke in the blast furnace, none are used to replace coke entirely.

Pig iron is the chief material input in raw steel production. The conversion of iron ore into pig iron takes place in a blast furnace, fueled mainly by coke. Pig iron is drawn from the furnace in a molten state, and is approximately 93 percent iron and 7 percent impurities. Once produced, the molten iron is utilized in one of two ways. In an integrated steel mill, the molten iron can be charged, with or without iron and steel scrap, into a steel furnace. Alternatively, the molten iron is poured into molds called "pigs" where it solidifies when cooled. In solid form, pig iron can be stored in the plant for later conversion into steel, or can be shipped to other facilities that produce steel.[8]

Raw steel is the primary manufacture of plants classified in SIC 3312. Produced in one of several types of steel furnaces, steel is substantially freer from impurities than pig iron.

The American Iron and Steel Institute identifies three major grades of steel--carbon, alloy, and stainless.[9] Carbon steel contains only small amounts of such alloying elements as vanadium, molybdenum, manganese, silicon, and copper.[10] Carbon steel is suitable for use in applications not requiring additional strength or other special properties. As most applications are of this type, carbon steel accounted for 85.3 percent by weight of U.S. raw steel production in 1979.[9]

Alloy steel consists of steels containing specific percentages of vanadium, molybdenum, or other elements as well as larger amounts of manganese, silicon, and copper than carbon steel. Tool steel is an alloy containing such elements as tungsten and molybdenum. Its added strength and hardness make it well suited for use in tools and power-driven cutting and shaping machinery. Another alloy, high-strength low-alloy steel, contains only small amounts of alloying elements, and is harder than carbon steel because of special processing.[10] Alloy steels are gaining relative importance in the steel market, increasing from 9.7 percent of total U.S. raw steel production by weight in 1970 to 13.2 percent in 1979.[9]

Stainless steel accounted for 1.6 percent by weight of U.S. raw steel production in 1979.[9] Most stainless steel is an alloy of steel, chrome, and nickel. Stainless steel is generally strong and highly resistant to rust and corrosion, making it particularly useful in medical, chemical, and aerospace applications.[10]

Raw steel exists as solid ingots and crude shapes such as slabs, billets, and blooms. Slabs, billets, blooms, and other semifinished shapes are suitable for rolling or otherwise processing into finished steel products. These semifinished products can either be continuously cast from molten steel direct from the furnace or can be formed from reheated steel ingots. Approximately 15 percent of U.S. produced raw steel is continuously cast; the rest is produced in ingot form.[11] [12]

The fourth major category of output of SIC 3312 is finished steel products. Included in this category are only very basic steel shapes such as plates, sheets, strips, rods, bars, and tubing. Establishments that produce these products are classified in SIC 3312 only if they are "hot-rolled" from iron and steel. Establishments that produce very similar products by a cold-finishing technique are classified in other SIC codes by the type of product. For example, the total value of output by all domestic industries of steel nails and spikes in 1977 was $359.0 million. Of this total, 43 percent was produced in SIC 3312 while 52 percent was produced in SIC 3315--steel wire and related products.[13] [14]

9.2.2.1.2 Production technology.

9.2.2.1.2.1 Raw materials and other inputs. Coke, iron, and steel production require a wide variety of material inputs. Some of these inputs, for example coal and iron ore, are nonrenewable resources. Others such as steel scrap are better labeled renewable. An examination of the goods and services that are purchased by plants classified in SIC 3312 reveals some information about how steel products are produced.

The 1972 input-output (I-O) model of the United States economy identifies 492 distinct goods and services that comprise all economic activity. The national I-O model can be used to determine the economic and technical interrelationships between all 492 "industries." One of the 492 sectors identified is SIC 3312--blast furnaces and steel mills.[7]

One feature of the I-O model allows a determination of the "recipe" for producing one dollar of output of SIC 3312. This recipe is an industry average, and several cautions should be voiced. First, different plants may use somewhat different mixes of inputs to produce the same kind of product. Second, a plant that produces, for example, only coke, will use quite a different set of inputs than a plant that produces only steel.

Both plants, however, are classified in SIC 3312. Third, this industry-average recipe is based on the U.S. economy in 1972. No more recent model is available. To the extent that input substitution has occurred in the steel industry since 1972, the input mix has changed.

Of the 492 input-output sectors, the 10 representing the largest input cost shares to the blast furnaces and steel mills industry are recorded in Table 9-1. Most interesting is that the input having the largest cost share in blast furnaces and steel mill products production is blast furnaces and steel mills products themselves. Table 9-1 indicates that the steel industry purchased 17.3 cents of its own output for every dollar of output it produced. This observation can be explained as follows. Producers of iron, who are classified in SIC 3312, purchase significant quantities of coke from coke plants, which are also classified in SIC 3312. Similarly, steel plants purchase pig iron. The relatively large size of this intraindustry input coefficient stresses the importance of vertical integration in the iron and steel industry.

The second most important input by value is iron ore, which represents an input cost share of 5.8 percent. The third and fourth most significant inputs by value are not goods at all, but services. For each dollar of output, producers in SIC 3312 purchased 3.7 cents of railroad transportation and 3.7 cents of wholesale trade services in order to have all other inputs delivered to their plants.

The 2.7 percent input cost share for coal is a reminder that coke producers are classified in SIC 3312 and that some integrated steel mills produce their own coke. Coal, of course, is the primary input in coke production.

Note finally that the purchase of iron and steel scrap represents the eighth largest cost share input. Few other industries purchase such a large share of scrap. This share can be explained by the importance of iron and steel scrap as a substitute for pig iron in raw steel production.

9.2.2.1.2.2 Production processes. As stressed earlier, coke, pig iron, raw steel, and finished steel products are all produced by plants classified in SIC 3312. The purpose of this section is to focus only on the production processes employed to produce the primary output of the industry--raw steel. A discussion of technological change and trends follows in Section 9.1.2.1.2.3.

TABLE 9-1. IMPORTANT INPUTS TO THE BLAST FURNACES AND STEEL MILLS INDUSTRY--SIC 3312[7] (1972)

Input	Share of total input cost (percent)
Blast furnace and steel mill products	17.3
Iron ore	5.8
Railroad transportation	3.7
Wholesale trade services	3.7
Coal	2.7
Industrial chemicals	2.0
Electrometallurgical products	2.0
Scrap	2.0
Electricity	1.7
Natural gas	1.4

The production of raw steel generally involves the introduction of some combination of pig iron, iron scrap, and steel scrap into a steel furnace. In the furnace the impurities in the input charge are oxidized at high temperature. Steelmaking technologies differ in the type of furnace used. There are three primary furnace types in use worldwide: the open hearth furnace, the basic oxygen furnace (BOF), and the electric arc furnace (EAF). The Bessemer type furnace, associated with the oldest steel-making process, has virtually disappeared from use.

The open hearth furnace is the oldest furnace type currently in use in the United States, and is the least prevalent. In 1979, only 14.1 percent of all raw steel produced in the United States was produced using an open hearth process.[9] In this process, pig iron, scrap, or both are placed in a long, shallow furnace made of dolomite or silica brick. Gas or oil is burned to produce a flame that heats the input charge from above the open furnace. Preheated combustion air, sometimes enriched with pure oxygen, is forced into the furnace to aid the oxidation of impurities.[15] [16]

One advantage of the open hearth furnace is its ability to handle a charge of all pig iron, all scrap, or any combination of both. This allows open hearth operators to utilize inputs in an economically efficient manner as relative prices change. The major disadvantage of the open hearth process is that the heating cycle time, up to 8 hours, is lengthy in comparison with the BOF or EAF process.[16] Due to the heat time required, the process consumes approximately 2.5 times as much energy (measured in Btu's) per ton of steel than does the electric arc process. The open hearth process is relatively labor intensive as well, requiring up to twice as many labor hours per unit of steel as the basic oxygen process.[17]

The BOF process accounted for 61.1 percent of all U.S. steel production in 1979.[9] The metal charge for a BOF must be largely molten furnace iron--seldom less than 70 percent. The remaining charge can be cold pig iron or scrap. A largely molten metal charge is necessary because supplemental heat is not added to a BOF as it is to an open hearth furnace. The sole heat source in a BOF is the latent heat in the molten charge itself.[18] Even without the addition of supplemental heat to a BOF, steel refining is achieved in a short period of time due to the introduction of large quantities of pure oxygen. The availability in recent years of large quantities of pure oxygen at low relative prices has made BOF steelmaking economically feasible.[19]

The chief advantage of BOF steelmaking is that pig iron is converted to steel in a period of approximately 45 minutes. Labor and certain other costs per ton of steel are thus substantially lower for the BOF process than for the open hearth process. The major disadvantage of the BOF process is that the charge must consist mainly of molten iron. A BOF shop must have access to a source of molten metal; it is therefore usually part of an integrated steel mill.

The EAF steelmaking process accounted for 24.9 percent of all U.S. steel production in 1979.[9] In the EAF process, solid iron and scrap steel are placed in the furnace. The EAF can accept a charge of up to 100 percent scrap. Charged electrodes in the iron and steel charge create an electric arc between the electrodes and the metal charge. The heat generated melts the charge. Because no impurities are added by fossil fuels, the EAF process is particularly well suited to the production of alloy steels and stainless steel.[20]

Because the EAF may be charged entirely with scrap, it need not be affiliated with an integrated plant. EAF facilities can be quite small relative to open hearth or basic oxygen furnace operations. Thus, they are relatively inexpensive to build and market entry is not prohibited by high start-up costs.

9.2.2.1.2.3 Technical potential for input substitution and production process innovation. This section discusses the technical potential for input substitution and process innovation in raw steel production. The distinction should be made between technical potential and economic potential.

Technical potential is purely an engineering concept regarding the physical ability to employ different inputs or processes to produce a certain output. Technical potential does not ensure economic potential. Innovation is economically feasible only if (1) technical innovation is possible, and (2) market conditions are such that profit-maximizing firms are willing to incorporate the technology. It is clear that if technical innovation is observed in the industry, it must be both economically and technically feasible. On the other hand, if technical innovation is not observed, only economic feasibility can be absolutely ruled out. Technical potential is thus a necessary, but not sufficient condition for adoption of the technology by firms.

Evidence generally indicates that considerable potential exists in a technical sense for process innovation. However, the domestic steel industry is frequently criticized for being slow to adopt new technologies.[21]

The very fact that significant quantities of steel are produced by three distinctly different basic processes supports the notion that process innovation has occured. Table 9-2 presents the percent of total raw steel produced in the United States from 1968 through 1979 by the three steelmaking processes. The increase in the proportion of steel produced by the basic oxygen and electric arc processes at the expense of the open hearth process is striking. BOF production increased from 37.1 percent of the total in 1968 to 61.1 percent in 1979. Over the same period, production by the EAF process nearly doubled.

Technological innovation within the steelmaking processes is evident as well. Preheating scrap metal allows more of it to be used in the basic oxygen process. BOF efficiency is also being increased by the practice of blowing oxygen into the metal charge from below as well as from above the surface.[22]

Significant technological advances of other types are also occurring. Perhaps the most significant change currently is the adoption of continuous casting technology. In continuous casting, freshly refined molten steel from the furnace is poured directly into a water-cooled mold. The hardening steel shape is mechanically pulled continuously from the bottom of the mold and cut into desired lengths. Bypassing the steel ingot stage and subsequent reheating saves energy, time, manpower and waste steel. EAF operators are most rapidly employing continuous casting.[11]

The major material input in raw steel production is metal--molten iron, pig iron and scrap steel. The technical potential for substitution between pig iron and scrap steel can be characterized in two ways. First, in the general activity labeled steelmaking, pig iron and scrap metal are excellent substitutes for each other. Second, within a defined steelmaking process, substitution potential varies greatly with the type of process.

TABLE 9-2. RAW STEEL PRODUCTION BY PROCESS TYPE[9]

Year	Open hearth (Percent)	Basic oxygen (Percent)	Electric arc (Percent)
1979	14.1	61.1	24.9
1978	15.5	60.9	23.6
1977	16.0	61.8	22.2
1976	18.3	62.4	19.2
1975	19.0	61.6	19.4
1974	24.4	56.0	19.7
1973	26.4	55.2	18.4
1972	26.2	56.7	17.8
1971	29.5	53.1	17.4
1970	36.5	48.2	15.3
1969	43.1	42.6	14.3
1968	50.1	37.1	12.8

When steelmaking is considered as a broadly defined, homogeneous activity, input substitution is excellent. The ferrous metal input can be anywhere between 100 percent pig iron (open hearth process) and 100 percent scrap (electric arc process). In practice, a mixture of pig iron and scrap is typical for the open hearth and BOF processes. Table 9-3 indicates that in 1978 the open hearth process consumed a 53.5 percent pig iron/46.5 percent scrap mixture. The pig-iron/scrap mixture was 72.1 percent/27.9 percent in basic oxygen steelmaking and 2.7 percent/97.3 percent in electric arc steelmaking.

Substitution potential between pig iron and scrap within a given steelmaking process varies, depending on the process. In the open hearth process, the ferrous charge can be all pig iron, all scrap, or any mixture.[24] However, as indicated in Table 9-3, pig iron has steadily comprised a little over half of the ferrous charge in open hearth process steel production in recent years.

The basic oxygen furnace is far less tolerant of input substitution than the open hearth furnace. The pig-iron/scrap mixture has not varied far from 70 percent/30 percent. Technological advances, though, are beginning to relax this constraint. By simultaneously bottom-blowing additional oxygen into the BOF and preheating the scrap input, scrap can comprise up to 42 percent of the ferrous charge.[22]

Electric arc furnaces have historically depended on scrap as their major input. Technically, though, the EAF can operate satisfactorily with a wide range of variation in pig-iron/scrap content.[25]

Substitution among fuel inputs is possible as well. Gas and oil work equally well in generating heat for the open hearth process. In a basic oxygen furnace, the molten ferrous charge itself is the heat source, but varying amounts of oxygen are utilized in the process.

9.2.2.2 Demand Conditions.

9.2.2.2.1 Historical demand trends. As indicated earlier, steel is an intermediate good; most sales are to other producing industries. Because of this, demand for it tends to increase in times of increasing business activity and decrease in times of slackening business activity.

Apparent consumption of steel mill products in the United States is defined as shipments from U.S. plants, plus imports, minus exports. It is a measure of how much steel, imported and domestic, U.S. buyers purchase.

TABLE 9-3. PIG IRON AND SCRAP INPUTS TO RAW STEEL PRODUCTION[23]

	Pig iron (Percent)	Scrap (Percent)
1978		
Open hearth	53.5	46.5
Basic oxygen	72.1	27.9
Electric arc	2.7	97.3
1976		
Open hearth	55.7	44.3
Basic oxygen	71.6	28.4
Electric arc	1.5	98.5
1974		
Open hearth	54.2	45.8
Basic oxygen	71.5	28.5
Electric arc	3.0	97.0

Table 9-4 depicts 11 years of U.S. apparent consumption of steel mill products and real gross national product (GNP). Note that the decline in real GNP from 1973 to 1975 is accompanied by a decline in apparent consumption of steel mill products. The recovery from 1976 to 1978 is marked by an increase in the demand for steel.

While apparent consumption of steel tends to rise and fall in step with general economic conditions, it has not increased at an annual rate equal to that of real GNP. The continuously compounded annual rate of growth of real GNP from 1969 to 1979 was 2.8 percent. The comparable growth rate for steel consumption was only 1.1 percent (Table 9-4). Possible reasons for the slow growth in steel demand relative to that in general economic activity will be discussed in Section 9.1.2.2.3.

9.2.2.2.2 Important users of steel mill products. Previously, the 1972 input-output table of the U.S. economy was used to identify major suppliers of inputs to SIC 3312--the blast furnaces and steel mills industry. The I-O table also indicates the value of output of steel mill products sold to each of the 492 industries. Table 9-5 identifies the 10 industries that received the most shipments from plants classified in SIC 3312 in 1972.

Table 9-5 indicates that the most important buyer of steel mill products in 1972 was the steel mill industry itself. This fact emphasizes the great degree of vertical integration in the industry. Coke producers sell their output to producers of pig iron who in turn sell pig iron to steel producers; all are classified in SIC 3312.

The next two most significant purchasers of steel mill products by value of goods purchased are the motor vehicle parts and accessories industry, which purchased 6.8 percent of all steel in 1972, and the automotive stampings industry, which purchased 6.3 percent of the total in that year. In 1979, 18.6 percent of all steel products was sold to a broadly defined "automotive" market.[29]

As shown in Table 9-5, the remaining seven of the 10 most significant purchasers of output of the steel industry are all industries that produce intermediate goods: metal cans (used to produce canned goods), fabricated structural metal (for building), fabricated plate work, etc. Again, the table stresses the intermediate nature of the goods produced in the steel industry.

TABLE 9-4. U.S. REAL GROSS NATIONAL PRODUCT AND APPARENT CONSUMPTION OF STEEL MILL PRODUCTS[26 27 28]

Year	Real GNP (10^9 1972 $)	Apparent consumption of steel mill products (10^3 Mg)
1979	1,431.6	104,270
1978	1,399.2	105,800
1977	1,340.5	98,365
1976	1,273.0	91,678
1975	1,202.3	80,738
1974	1,217.8	108,485
1973	1,235.0	111,133
1972	1,171.1	96,698
1971	1,107.5	92,981
1970	1,075.5	88,070
1969	1,078.8	93,133

TABLE 9-5. IMPORTANT PURCHASERS OF OUTPUT FROM THE BLAST FURNACES AND STEEL MILLS INDUSTRY--SIC 3312[7] (1972)

Purchasing industry	Percent of total SIC 3312 output purchased
Blast furnaces and steel mill products	17.3
Motor vehicle parts and accessories	6.8
Automotive stampings	6.3
Metal cans	5.6
Fabricated structural metal	4.5
Fabricated plate work	3.3
Screws, bolts, nuts, rivets, washers	2.3
Iron and steel forgings	2.1
Miscellaneous fabricated wire products	2.1
Sheet metal work	1.9

9.2.2.2.3 Competing products. Section 9.1.2.2.1 indicated that the growth rate in the demand for steel has lagged behind the growth rate in real GNP in recent years. Section 9.1.2.2.2 emphasized that steel mill products are primarily intermediate goods used in the production of other intermediate goods. It is possible that the relatively slow increase in demand is due to the degree of substitution potential that exists between steel and competing materials for use in the production of other goods. This section addresses this issue.

As stated previously, 18.6 percent of all steel was purchased by automotive producers in 1979. According to one examination:

> ... the longer-range probabilities for more shipments [of steel] to this area [automotive] do not look good. Fuel economy regulations legislated by the government have compelled automobile manufacturers to design more efficient cars. This has meant not only smaller autos [which use less steel], but cars that contain proportionately less steel....[30]

The chief materials being substituted for steel in automobile production are aluminum and plastic, which are being well accepted.

The substitution of aluminum for steel is also having an adverse impact on the demand for steel by beverage container manufacturers. Even though canned beverage consumption continues to increase, steel shipments to the container market peaked in 1974.[31]

Steel faces competition from materials on many fronts. In construction, steel competes with concrete and, to a lesser extent, aluminum. Aluminum has replaced steel in some facets of ship construction. Polyvinyl chloride pipe and tubing are major competitors to the steel counterparts.[32]

9.2.3 Market Structure

In 1977 there were in total 396 blast furnaces and steel mill companies. This represents an increase of 64.3 percent from the 241 companies in 1972. From 1967 to 1972, the number of companies increased only 20.5 percent, from 200 in 1967.[3] This is an interesting observation in that apparent steel consumption grew at least as quickly in this 5-year period as in the latter (1972-1977). The most plausible explanation is market entry in recent years by small companies operating small, electric arc furnace mills. This issue is addressed later in section 9.1.3.2.

9.2.3.1 Geographic Distribution of Plants. The influence of basic supply conditions on market structure is also apparent in the effect on geographic distribution. Basic oxygen furnace plants and, to a lesser extent, open hearth plants, favor plant integration. In turn, integrated plants are ideally located near sources of coal and iron ore. Electric arc furnace plants, however, utilize scrap as their major input. Thus, EAF facilities are less tied to coal and ore producing regions of the country.

The geographic distribution of plants bears this out. In 1972, 50.0 percent of all plants were located in five states: Pennsylvania, Ohio, Indiana, Illinois, and Michigan. These states contain coal and ore production sites. In 1977, only 38.9 percent of all plants were located in these same states.[33] [34] As EAF steel production increased from 17.8 percent of the total in 1972 to 22.2 percent of the total in 1977 (see Table 9-2), geographic concentration became less pronounced.

Fully integrated plants, which need coal to produce coke, and ore to produce iron, are as expected, concentrated in the five states listed above. In 1977, 65.7 percent of all fully integrated plants were located in these five states.

9.2.3.2 Firm Concentration. Basic supply conditions affect industry concentration ratios. The greater the proportion of total output produced by a given number of the largest firms, the more concentrated the industry.

Raw steel production would be expected to become less concentrated as more steel is produced by smaller, less integrated EAF facilities. Because EAF facilities need not be part of an integrated operation, they are less costly to build. One estimate places the cost (per ton of annual output) of building an integrated steel mill at almost six times that for building a small electric arc furnace plant.[35]

The four largest domestic producers of steel mill products together shipped 53.7 percent of total market tonnage in 1974. In 1979 these same producers, still the four largest, accounted for only 49.8 percent of all shipments.[36]

Recent market entry by small, electric arc furnace steel plants is credited in part with reducing industry concentration. One analyst estimates that the so-called "mini-mills" accounted for 13 percent of domestic steel shipments in 1978, and forecasts that they will capture at least 25 percent of the market by 1990.[35]

9.2.3.3 Vertical Integration. As indicated, certain steel production technologies favor some degree of integration. A plant that produces steel using the basic oxygen process, for example, requires a ferrous charge comprised largely of molten iron. The molten iron can most efficiently be transferred directly from the blast furnace where it is produced, never having cooled. Conversion of iron ore into iron in the blast furnace in turn requires coke. Coke can be purchased from other plants, but is frequently produced in the same establishment.

Production of steel via the electric arc furnace requires little plant integration. As cold scrap is the usual ferrous charge, neither blast furnace-produced molten iron nor coke is necessary.

The 1977 Census of Manufactures indicates that there were 504 plants classified in SIC 3312 in that year. This is an increase of 38.5 percent from the 364 plants reported by the Census in 1972. In Table 9-6, the plants classified in SIC 3312 are further classified by degree of integration for the years 1972 and 1977. Plants that produce coke, iron, raw steel, and finished steel are regarded as "fully integrated." Plants that produce iron, raw steel and finished steel, or just raw steel and finished steel may be considered "partially integrated." Plants that produce only one of these four products are called "nonintegrated."

As shown in Table 9-6, the proportion of total plants that were fully integrated declined from 10.7 percent in 1972 to 6.9 percent in 1977. Over the same period, the percent of total plants that were partially integrated declined from 23.1 in 1972 to 19.7 in 1977. Nonintegrated plants, however, increased from 66.2 percent of the total in 1972 to 73.4 percent in 1977.

The trend towards nonintegrated plants is an example of basic supply (technological) conditions influencing market structure. Table 9-2 indicated a substantial increase in the production of steel by the electric arc process since 1972. This trend towards a technology requiring little plant integration may account for the shift away from plant integration.

9.2.3.4. Horizontal Integration. Horizontal integration is defined here as diversification into the production of nonsteel goods or services by steel firms. Integration of this type is evidenced by firms in the steel industry. One estimate indicates that as much as 25 percent of total sales by U.S. steel firms are nonsteel.[39]

TABLE 9-6. PLANT INTEGRATION[37 38]

Degree of integration	Percent of total plants 1972	 1977
Coke, iron, raw steel, finished steel	10.7	6.9
Iron, raw steel, finished steel	3.6	3.4
Raw steel, finished steel	19.5	16.3
Single product or other combination	66.2	73.4
Total plants (no.)	364	504

Inadequate profit margins in steelmaking, to be discussed later in this profile, are frequently cited as the reason for diversification by steel firms. Petroleum, chemicals, and financial services are among the industries in which steel companies have invested. Diversification is expected to continue. Investment in nonsteel enterprises by steel manufacturers presently accounts for 20 percent of their total investment.[40]

9.2.3.5 Economies of Production.

9.2.3.5.1 Long-run cost structure. An industry is said to have an increasing (decreasing) cost structure if the expansion of industry output over time increases (decreases) the real, average total cost of producing one unit of output. The long-run cost structure of the steel industry is examined here under the assumption that price equals average total cost.

From 1961 to 1979, U.S. raw steel production (in tons) increased at a continuously compounded average annual rate of 1.8 percent.[28] [41] During this same 18-year period, the nominal price of steel increased at an average annual rate of 6.2 percent.[42] That part of the nominal price increase attributable to inflation can be removed by deflating the nominal estimate by the increase in the general price level (as measured by the implicit price deflator) over the same period. The implicit price deflator was estimated at 4.8 percent per year over this period; therefore the real price of steel increased 1.4 percent per year from 1961 to 1979. An increasing long-run cost structure is thus indicated for the steel industry.

9.2.3.5.2 Short-run cost structure.

9.2.3.5.2.1 Economies of scale. The presence or absence of economies of scale is often cited as being partially responsible for determining short-run cost structure. There is general agreement that significant economies of scale do exist in steel production; that is, physical output increases more than proportionately with all inputs. The Office of Technology Assessment of the U.S. Congress states that domestic steel producers, because they have smaller, higher cost plants than their foreign counterparts, are less able to realize economies of scale.[43] The U.S. General Accounting Office says "...bigger is cheaper in integrated steelmaking. Large-scale plants can more efficiently use equipment, labor, and energy than small plants."[44] The same report follows with an estimate of

4 million tons of output (of raw steel) annually as a minimum economically efficient plant scale.

Economies of scale and minimum efficient scale are however, determined in part by the technology the plant employs. Many new steel companies are operating electric arc furnace plants with capacities under 0.5 million Mg annually. Far from being uneconomic, these small plants are able to sell raw steel below prices charged by integrated mills, and still profit.[35] Further advances in steelmaking technology could further reduce the presence of economies of scale.

9.2.3.5.2.2 Production costs and plant vintage. There is a definite link between steel production costs and plant age. In general, per unit costs of steel production are higher for older plants than for newer plants. The General Accounting Office maintains that the obsolescence of U.S. steel plants is the industry's major obstacle in meeting domestic steel demand.[45]

The cost-age relationship is primarily the result of technological advance over time. Electric arc furnaces can produce steel at lower cost than the open hearth or basic oxygen furnaces. Newer plants increasingly adopt the electric arc process, hence newer plants are lower cost operations.

9.2.3.6 Entry Conditions. The U.S. steel industry has long been regarded as presenting barriers to potential market entrants.[46] Entry is said to be difficult because the very large minimum efficient plant scale makes for a substantial initial capital investment. One estimate places the cost of a new integrated steel mill at $1,107 per Mg of capacity, in 1978 dollars.[35] This would put the capital cost of a 4 million Mg plant (the previously mentioned estimate of the minimum efficient plant scale) at nearly $5 billion.

That barriers to entry are actually restrictive is not clear from Census data. In 1967, 200 companies operated one or more establishments classified in SIC 3312. The number of companies increased 20.5 percent from 1967 to 1972, for a total of 241 companies in 1972. Market penetration was even more pronounced from 1972 to 1977. A total of 396 companies operated in SIC 3312 in 1977, an increase of 64.3 percent from 1972.[3]

Much of the dramatic increase in the number of new companies since 1972 is no doubt the result of new, small-scale, electric arc furnace plant operations. "Mini-mills" are less expensive to build because blast furnace and coking facilities are unnecessary. An estimate for building a new mini-mill is $192 per Mg of capacity in 1978 dollars--far under the $1,107 estimate for an integrated mill.[35] Removal of the start-up cost barrier is significant. Entry barriers of other types appear to be minimal.

9.2.4 Market Conduct

This section focuses mainly on pricing behavior in the steel industry. The question is whether the steel industry most closely approximate the competitive pricing model, the monopoly pricing model, or some model of imperfect competition. Important considerations are homogeneity of product, degree of industry concentration, barriers to entry, and observed pricing practices.

9.2.4.1 Homogeneity of Product. The degree to which the output of an industry is perceived by demanders to be homogeneous is an important determinant of industry pricing behavior. The more homogeneous the product, the more likely a single market price will be observed. A perfectly homogeneous good is difficult to sell at some price higher than that offered by one or more competitors. Interestingly, in his discussion on this subject, Nicholson suggests steel girders as one tentative example of a strictly homogeneous good.[47]

The degree of product homogeneity in the steel industry is not easily determined. Section 9.1.2.1.1 of this profile suggests four major categories of products produced by establishments classified in the blast furnaces and steel mills industry--coke, pig iron, raw steel, and finished steel products. These products differ greatly from one another in use. Coke, for example, is of no interest to a construction firm demanding steel girder. The price for a megagram of coke would not be equivalent to that for a megagram of steel girder; the two are not homogeneous products.

A meaningful discussion of product homogeneity cannot proceed without some reasonable limitation of product definition. Section 9.1.2.1.2.2 of this profile, which discusses production processes employed in SIC 3312, concentrates on the primary output of the industry--raw steel. The same approach will be adopted here. The relevant question is whether raw steel is perceived by buyers to be homogeneous.

In 1979, approximately 85 percent of all raw steel was carbon steel, the remainder was alloy and stainless.[9] Raw carbon steel is produced as ingots, blooms, slabs, billets, and other semifinished shapes. All of these shapes resemble one another in that they are, to varying degrees, square, blocky, solid forms with rounded edges. All are similar in that they are not useful in these forms, but must be rolled, drawn or otherwise processed into more finished shapes such as girders, rails, bars, rods, sheets, pipe, and plates.

Scherer compares the homogeneity of steel with that of cement and rayon.[48] Any differences in steel, he argues, are superficial. There may be complex differences in finish, temper, packaging, etc., but steel is fairly homogeneous.[49] The Federal Trade Commission says that within each steel product line, steel is relatively homogeneous; the product of one plant is physically substitutable for the product of another.[50]

Homogeneous output alone does not ensure a single pricing model. A strictly homogeneous product can be produced under perfect competition, monopoly, or any other market model.[51] It becomes necessary to investigate other indicators of pricing behavior. However, recognizing the hazards of such a generalization, product homogeneity will be assumed for raw steel.

9.2.4.2 Degree of Concentration. Industry concentration largely determines market pricing behavior. At the one extreme, where all industry output is produced by a single firm, the pure monopoly pricing model is most relevant. The other extreme is an industry characterized by many sellers, with no one firm producing a significant share of total output. A perfect competition pricing model is then applicable. Either extreme is rare, and the steel industry is neither extreme.

The U.S. steel industry is clearly not a pure monopoly. In 1977 there were 396 companies with plants classified in SIC 3312.[3] Whether the existence of 396 companies justifies the use of a perfect competition pricing model is less clear. For perfectly competitive pricing practices to result, it is not sufficient that a large number of firms exist. No one firm must produce a large enough share of industry output to enable it to influence market price by its own actions. In 1979, the single largest domestic steel firm, U.S. Steel, accounted for 20.8 percent of total domestic steel shipments.[52] This large market share of a single producer brings into question the appropriateness of the perfectly competitive pricing model for the industry.

9.2.4.3 Barriers to Entry. The degree to which barriers to entry effectively reduce market penetration by new firms influences industry pricing behavior. Nicholson calls barriers to entry the source of all monopoly power.[53] Section 9.1.3.6 concludes that effective barriers to entry do not exist in the steel industry.

The apparent lack of significant barriers to entry promotes the selection of the perfectly competitive pricing model. "Free" market entry is necessary but not sufficient to support this model. "Free" market entry obtains when the only costs of production incurred by new firms are those incurred by established firms.[54] In the case of the steel industry, economies of scale enjoyed by existing firms once resulted in lower per unit cost of production. Technological advances, especially the development of the electric arc furnace, have apparently diminished this technological advantage, as evidenced by recent market entry.

9.2.4.4 Observed Pricing Practices. The purpose of this section is to comment on actually observed pricing practices in the steel market as another aid in selecting an appropriate pricing model. If market participants behave as perfect competitors, a perfect competition model would logically be deemed appropriate. If evidence of imperfect competition behavior is apparent, other market models must be explored. Emphasis will be placed on observed pricing behavior in recent times--the past 20 years.

Selection of the past 20-year period for examining pricing behavior is not entirely arbitrary. Until the 1960's, the U.S. steel industry had a long history of adherance to a pattern of rigid administered pricing. During normal times in the period prior to the 1960's, U.S. Steel Corporation, with a market share exceeding one half, assumed the role of price leader and its smaller rivals followed.[55]

In the 1960's and 1970's, pricing behavior has been complicated by two factors. First is the competition provided by foreign steel supply. Second is the industry structural change resulting from changing basic conditions, especially technological advance.

Pricing behavior in the domestic steel industry is most frequently said to be characteristic of an oligopolistic market. An oligopoly is a market with relatively few firms producing a homogeneous product. A single firm in an oligopoly can have some effect on the price it will receive for its output because it has a significant market share of the total output.[56]

Smolik cites the U.S. steel industry as being a "... concentrated oligopoly on the basis of concentration ratios and on the basis of its highly knit social structure." The oligopolistic structure, he argues, is further strengthened by the homogeneous nature of most steel products.[57]

Adams (writing in 1977) states:

> The steel industry today is--structurally speaking--an oligopoly and is dominated by a relatively few, large, integrated producers. These, taken together, own or control about three quarters of the nation's . . . ingot and "steel for casting" capacity . . . .[58]

Unfortunately, a tentative conclusion that the American steel industry is an oligopoly makes it more difficult, not easier, to identify a specific pricing behavior model. There are no generally accepted pricing behavior models for oligopolists as there are for perfect competitors and monopolists. Many price-output combinations can result based on various sets of behavioral assumptions. Observation of actual oligopoly markets suggests that almost anything can happen.[59] [60]

One generalization that perhaps can be made is that some form of administered pricing behavior will emerge under oligopoly. The outcome of a single firm in an oligopoly changing its output price depends, in part, on the reactions of other firms. A firm stands to suffer if it cannot accurately determine beforehand how its actions will be met by other firms. Prices tend to be fixed until some unifying event can ensure the "appropriate" response by all firms.[61]

A system of price leadership often emerges in oligopoly. If a single firm is recognized as the price leader, price adjustments can occur with some assurance of market order as other firms follow in concert.

Price leadership has been an apparent characteristic of the U.S. steel industry. U.S. Steel Corporation is the usually recognized price leader. All other companies follow the leader's actions closely.[57] [62] As recently as 1971, an announcement of a price hike for all mill products by U.S. Steel Corporation was promptly followed by a similar declaration by other major producers.[63] When the U.S. General Accounting Office in 1979 asked steel users why they buy foreign steel, one answer given was that they, as buyers, perceived that many U.S. mills follow suit each time a major steel mill publishes a new price list.[64]

While there is near universal agreement that the domestic steel industry has historically been oligopolistic with U.S. Steel Corporation acting as price leader, trends in recent years indicate the situation is changing or has changed. The reason for this basic change in market conduct is, once again, changes in market structure. Three structural changes have been observed.

First, the Federal Trade Commission reports that since 1960, U.S. Steel Corporation has had to share the role of leader with Armco Steel and Bethlehem Steel. Efforts to raise prices by any leader have frequently been ignored unless they reflected basic supply and demand conditions.[65]

A second major structural change has been the dramatic increase in steel output by independent "mini-mills." Mini-mills regularly engage big producers in price competition, and are beginning to be a greater threat to historically large steelmakers than are foreign producers.[35 66] The success of mini-mills is in turn the result of a successful technological advance--the electric arc furnace. This is an example of how changes in basic conditions can, by influencing market structure, ultimately result in changes in market conduct.

The third major structural change is the increasingly significant role of steel imports. In 1961, imported steel mill products accounted for only 4.7 percent of United States consumption. This import market share increased to 13.8 percent in 1970 and reached a peak of 18.1 percent in 1978.[28 41]

Steel imports may significantly affect the price behavior of domestic steel firms. If the U.S. steel industry is an oligopoly, U.S. Steel Corporation is the dominant firm, with steel shipments of 19.0 million Mg in 1979.[52] In that same year, total steel mill imports totaled 15.9 million Mg--83.7 percent of the dominant firm's output.[28] As foreign producers collectively capture more of the U.S. market, domestic firms individually and collectively enjoy less market power.

To summarize, it is not easily concluded that currently observed pricing behavior in the steel industry is oligopolistic. Increasingly, individual firms are setting their own price based mainly on their own cost structures and basic underlying supply and demand conditions.

9.2.5 Market Performance

In a conditions-structure-conduct-performance industry profile, the performance section is of special importance. Market performance is seen as the result of the earlier causal chain. Emphasis in this section will be on three aspects of market performance. First, a financial profile of the steel industry will be presented with comments and comparisons to other industries. Second, recent trends in such industry variables as price, output, employment, and investment will be presented. Third, industry projections will be discussed.

9.2.5.1 Financial Profile of the Steel Industry. The objective of a firm is to maximize shareholders' wealth. It can be shown that a firm that maximizes profit, maximizes the discounted stream of cash flows to its shareholders.[67] If this is accepted as the primary objective of firms, some measure of success in achieving this objective is surely a relevant measure of financial performance.

Stockholders' equity is the portion of a corporation's assets owned by holders of common and preferred stock. It is equal to the excess of a firm's assets over its liabilities.[68] A ratio frequently used to assess a firm's success in maximizing shareholder's wealth is after-tax profit to stockholders' equity. An average of this ratio for firms representing approximately 90 percent of raw steel output over the period 1960-1979 is presented in Table 9-7. As a comparison, the same ratio is presented for firms representing all manufacturing over the same period.

A profit-to-equity ratio of 10 percent or higher is usually regarded as necessary to provide dividends to the holders of stock, as well as funds for future growth.[72] The 20-year average profit-to-equity ratio for all manufacturing, as calculated from the data presented in Table 9-7, is 13.0 percent. The 20-year average for the steel industry is considerably lower--7.4 percent. In only one year, 1974, was the ratio for steel firms equal to or greater than that for all manufacturing. The profitability difference as measured by this ratio between steel and other industry is even more pronounced in recent years. During the period 1970-1979, average annual return to steel stockholders was only 7.2 percent, compared to 13.8 percent for all manufacturing stockholders.

TABLE 9-7. AFTER-TAX PROFIT TO STOCKHOLDERS' EQUITY[69,70,71]

Year	Steel (Percent)	All manufacturing (Percent)
1979	6.8	16.7
1978	7.3	15.9
1977	0.1	14.9
1976	7.8	15.0
1975	9.8	12.6
1974	17.1	15.2
1973	9.3	14.9
1972	5.8	12.1
1971	4.3	10.8
1970	4.1	10.1
1969	7.0	12.4
1968	8.2	13.3
1967	6.9	12.6
1966	8.9	14.2
1965	9.4	13.9
1964	9.0	12.6
1963	7.3	11.6
1962	5.3	10.9
1961	6.5	9.9
1960	7.9	10.6

These figures tend to support the contention by Adams that the steel industry's profit record has been poor in recent years. Adams blames the industry's noncompetitive pricing conduct, leading to technological lethargy and inadequate capacity utilization, for low profitability.[73]

9.2.5.2 Financial Profile of Firms Owning Electric Arc Furnace Facilities. In 1980, 80 independent companies either owned EAF facilities or owned smaller companies that owned EAF facilities. These 80 companies are listed in Table 9-8, along with financial data for the 42 firms for which such data are readily available. The remaining 38 firms are believed to be relatively small.

Several financial ratios have been calculated for each firm for which data are available. These ratios are presented in Table 9-9.

The liquidity ratio is a measure of the firm's ability to meet current obligations as they come due. A liquidity ratio above one indicates the firm can meet current obligations with little trouble. A firm with a liquidity ratio below one may be unable to pay bills on time, which may lead to the firm's demise.[75] Firms operating EAF facilities evidenced liquidity ratios that varied from 1.25 to 3.15 in 1979.

The profit ratio measures the ability of the firm to pay dividends to stockholders while maintaining adequate funds to ensure growth. A ratio of 10 percent or higher is usually deemed necessary to secure these ends.[72] Sixteen EAF firms had profit ratios in 1979 below 10 percent and two firms, Penn-Dixie and United States Steel, had negative profit ratios. A total of 17 firms had profit margins in excess of 15 percent.

The leverage ratio indicates the relationship between total debt and stockholders' equity. A ratio exceeding one indicates the firm is mainly financed by debt. While it is difficult to say what the highest satisfactory ratio is, in general the higher the ratio, the more likely that the firm is unable to meet its long-term obligations. Of the 42 firms, 26 had ratios exceeding one in 1979, indicating they are substantially debt financed.

Table 9-10 lists the simple (unweighted) means of the three ratios for the 42 EAF companies. Also listed are industry average ratios for several other industries for the same year. While it is difficult to draw conclusions, observations can be made. The mean liquidity ratio for EAF firms

TABLE 9-8. U.S. COMPANIES OPERATING ELECTRIC ARC FURNACES: FINANCIAL DATA IF AVAILABLE (1979)

Company	Current Assets	Current Liabilities	Profit	Equity	Total Assets= Total Liabilities	Debt
Al Tech Specialty Steel	.	.	.	.	.	.
Allegheny Ludlum Industries	526,123	261,973	71,527	485,154	1,140,165	655,011
Ameron	107,806	40,849	8,719	100,555	191,968	91,413
Armco	1,361,643	656,741	221,040	1,715,271	3,260,163	1,544,892
Atlantic Steel	.	.	.	.	.	.
Auburn Steel	.	.	.	.	.	.
Babcock and Wilcox	.	.	.	.	.	.
Bayou Steel	.	.	.	.	.	.
Bethlehem Steel	1,844,200	1,035,900	275,700	2,639,800	5,165,900	2,526,100
Border Steel	.	.	.	.	.	.
Braeburn Steel	.	.	.	.	.	.
Cabot Corporation	476,205	234,074	70,445	399,784	942,973	543,189
California Steel	.	.	.	.	.	.
Calumet Steel	.	.	.	.	.	.
Cameron Iron Works	373,762	142,678	58,412	322,181	627,862	305,681
Carpenter Technology	184,374	80,618	40,740	226,872	322,477	95,605
Cascade Rolling Mills	.	.	.	.	.	.
Ceco Steel	133,694	50,543	13,273	105,383	188,978	83,595
CF&I Steel	130,424	82,552	15,371	213,123	400,217	187,094
Chaparral Steel	65,289	35,819	30,258	93,695	232,455	138,760
Columbia Tool Steel	.	.	.	.	.	.
Connors Steel	175,994	87,257	23,950	147,741	333,657	185,916
Copperweld	153,773	78,099	23,078	151,883	312,816	160,933
Crucible	854,182	335,534	111,375	638,479	1,301,619	663,140
Cyclops	256,988	133,378	5,263	168,037	402,580	234,543
Eastern Stainless Steel	126,347	47,578	8,183	77,904	175,874	97,970
Edgewater Steel	.	.	.	.	.	.
Finkel and Sons	.	.	.	.	.	.
Florida Steel	65,041	24,039	14,468	71,696	126,158	54,462

TABLE 9-8. (Continued)

Company	Current Assets	Current Liabilities	Profit	Equity	Total Assets= Total Liabilities	Debt
Ford Motor Company	11,571,300	9,263,000	1,169,300	10,420,700	23,524,600	13,103,900
Georgetown Steel	.	.	.	.	.	.
Hawaiian Steel	.	.	.	.	.	.
Ingersol Rand	1,557,139	634,447	149,342	1,095,039	2,128,410	1,033,371
Inland Steel	813,687	567,441	131,108	1,321,351	2,725,473	1,404,122
Intercoastal Steel	.	.	.	.	.	.
Interlake	383,477	221,207	39,735	349,944	733,559	383,615
ITT	7,026,244	5,621,157	380,685	5,621,157	15,091,321	9,470,164
Jessop Steel	104,805	46,767	3,337	53,470	182,141	128,671
Jones & Laughlin	1,934,223	1,132,659	173,527	757,242	3,864,757	3,107,515
Earle M. Jorgenson	106,149	39,055	20,174	128,887	182,858	53,971
Joslyn Stainless Steels	.	.	.	.	.	.
Judson Steel	.	.	.	.	.	.
Kentucky Electric Steel	.	.	.	.	.	.
Keystone Consolidated	142,918	65,934	757	113,693	255,310	141,617
Knoxville Iron	.	.	.	.	.	.
Laclede Steel	.	.	.	.	.	.
Lonestar Steel	961,500	409,900	172,200	923,600	2,196,700	1,273,100
Lukens Steel	95,703	52,543	7,467	141,262	247,989	106,727
Marathon Steel	561,800	353,400	57,000	1,335,000	5,392,400	4,057,400
Mclouth Steel	196,630	136,814	9,368	189,226	465,795	276,569
National Forge	.	.	.	.	.	.
National Steel	1,275,417	732,133	126,466	1,436,825	3,160,279	1,723,454
New Jersey Steel & Structure	.	.	.	.	.	.
North Star Steel	.	.	.	.	.	.
Northwestern Steel and Wire	.	.	.	.	.	.
Nucor	117,362	63,536	42,265	133,737	243,112	109,375
Oregon Steel Mills	.	.	.	.	.	.
Owens Electric Steel	.	.	.	.	.	.
Penn-Dixie Steel	89,479	59,311	-47	72,478	190,952	118,474
Phoenix Steel	69,528	43,859	3,767	61,344	138,307	76,963

TABLE 9-8. (Continued)

Company	Current Assets	Current Liabilities	Profit	Equity	Total Assets= Total Liabilities	Debt
Quanex	79,987	37,355	13,131	70,226	147,600	77,374
Raritan River Steel	.	.	.	.	.	.
Republic Steel	923,525	570,117	121,158	1,489,198	2,749,872	1,260,674
Roanoke Electric	.	.	.	.	.	.
Roblin Steel	38,514	23,312	642	25,172	91,589	66,417
Ross Steel Works	.	.	.	.	.	.
Sharon Steel	597,106	323,763	58,603	257,300	1,110,779	853,479
Simonds Steel	250,810	79,742	35,455	190,695	373,172	182,477
Soule Steel	.	.	.	.	.	.
Timet	.	.	.	.	.	.
Structural Metals	.	.	.	.	.	.
Teledyne Vasco	747,610	407,697	371,960	1,747,979	2,027,197	279,218
Tennessee Forging Steel	.	.	.	.	.	.
Texas Steel	.	.	.	.	.	.
Timken Steel	455,413	177,031	102,131	705,859	942,912	237,053
Union Electric Steel	.	.	.	.	.	.
United States Steel	3,456,700	2,410,800	-293,000	5,394,600	11,029,900	5,635,300
Washburn Wire	.	.	.	.	.	.
Washington Steel	158,379	116,846	11,392	53,301	209,999	156,698
Witteman Steel Mills	.	.	.	.	.	.

TABLE 9-9. FINANCIAL RATIOS FOR U.S. COMPANIES OPERATING ELECTRIC ARC FURNACES (1979)

Company	Current Ratio	Leverage Ratio	Percent Profit
Allegheny Ludlum Industries	2.01	1.35	14.74
Ameron	2.64	0.91	8.67
Armco	2.07	0.90	12.89
Bethlehem Steel	1.78	0.96	10.44
Cabot Corporation	2.03	1.36	17.62
Cameron Iron Works	2.62	0.95	18.13
Carpenter Technology	2.29	0.42	17.96
Ceco Steel	2.65	0.79	12.60
CF&I Steel	1.58	0.88	7.21
Chaparral Steel	1.82	1.48	32.29
Connors Steel	2.02	1.26	16.21
Copperweld	1.97	1.06	15.19
Crucible	2.55	1.04	17.44
Cyclops	1.93	1.40	3.13
Eastern Stainless Steel	2.66	1.26	10.50
Florida Steel	2.71	0.76	20.18
Ford Motor	1.25	1.26	11.22
Ingersol Rand	2.45	0.94	13.64
Inland Steel	1.43	1.06	9.92
Interlake	1.73	1.10	11.35
ITT	1.25	1.68	6.77
Jessop Steel	2.24	2.41	6.24
Jones & Laughlin	1.71	4.10	22.92
Earle M. Jorgenson	2.72	0.42	15.65
Keystone Consolidated	2.17	1.25	0.67
Lonestar Steel	2.35	1.38	18.64
Lukens Steel	1.82	0.76	5.29
Marathon Steel	1.59	3.04	4.27
McLouth Steel	1.44	1.46	4.95
National Steel	1.74	1.20	8.80
Nucor	1.85	0.82	31.60
Penn-Dixie Steel	1.51	1.63	-0.06
Phoenix Steel	1.59	1.25	6.14
Quanex	2.14	1.10	18.70
Republic Steel	1.62	0.85	8.14
Roblin Steel	1.65	2.64	2.55
Sharon Steel	1.84	3.32	22.78
Simonds Steel	3.15	0.96	18.59
Teledyne Vasco	1.83	0.16	21.28
Timken Steel	2.57	0.34	14.47
United States Steel	1.43	1.04	-5.43
Washington Steel	1.36	2.94	21.37

TABLE 9-10. FINANCIAL RATIOS FOR SELECTED INDUSTRIES[76]
(1979)

Industry	Liquidity ratio	Profit ratio	Leverage ratio
EAF steel firms[a]	1.99	13	1.33
Primary nonferrous metals, NEC--SIC 3339	1.86	22	2.32
Aluminum foundries--SIC 3361	2.15	22	1.84
Primary metal products, NEC--SIC 3399	2.28	24	0.69
Motor vehicles--SIC 3711	1.73	17	1.44
Petroleum refining--SIC 2911	1.36	26	1.56

[a] Means from Table 9-9.

is in line with other industry averages. These firms should generally be able to meet current obligations with little difficulty. The mean EAF profit ratio is below that of all other industries presented. Finally, there is no evidence that EAF firms are too heavily debt financed, based on a comparison with the leverage ratios of the other industries.

9.2.5.3 Industry Trends. The purpose of this section is to highlight recent trends in certain steel industry variables. The variable values presented and the related discussion are intended only as an indication of past industry performance. Projections of future performance are presented in Section 9.1.5.4.

9.2.5.3.1 Physical output. The annual physical output of an industry is perhaps the single best indicator of industry performance. In general, a healthy industry is expected to increase physical production in pace with general economic activity. As the population increases and real income increases, the demand for industry output is expected to increase. An annual index of shipments of domestically produced steel mill products tonnage has been constructed and is presented in Table 9-11. In the same table is the total industrial production index of the U.S. Board of Governors of the Federal Reserve System. Both are indexes of actual physical output.

It is clear from Table 9-11 that during the 13 years ending in 1979, steel production did not keep pace with total industrial production. The average annual continuously compounded rate of growth of total industrial output was 3.5 percent, compared with only 1.5 percent for steel mill products. Of the period covered, domestic steel shipments peaked in 1973. The two-year decline in the total industrial output index in 1974-1975 marks a recession. Steel output declined as well during those years, but has been far slower to recover than the overall economy.

9.2.5.3.2 Real value of output. Because of the effect of inflation, observation of the value of industry output over time can be misleading. Industry value of output is more meaningful when deflated to constant dollars for some base year.

Table 9-12 presents the real value of output (deflated by the implicit price deflator for Gross National Product) of all establishments classified in SIC 3312 from 1967 to 1977. The annual growth rate for real output of

TABLE 9-11. STEEL MILL PRODUCTS AND TOTAL INDUSTRIAL OUTPUT INDEXES (1967 = 100)[28 41 77 78]

Year	Steel mill products	Total industrial output
1979	119.5	152.5
1978	116.7	146.1
1977	108.6	137.1
1976	106.6	129.8
1975	95.3	117.8
1974	130.5	129.3
1973	132.8	129.8
1972	109.4	119.7
1971	103.7	109.6
1970	108.2	107.8
1969	111.9	111.1
1968	109.5	106.3
1967	100.0	100.0

TABLE 9-12. REAL VALUE OF OUTPUT FOR SIC 3312 (10^6 1967 $)

Year	Real value of output
1977	23,487.6
1976	23,423.5
1975	22,157.2
1974	28,382.8
1973	22,679.4
1972	18,922.7
1971	18,081.9
1970	23,360.0
1969	20,319.8
1968	20,251.8
1967	19,620.6

SIC 3312 was 1.8 percent during the period, well below the 2.4 percent growth rate of real GNP.[26,27]

9.2.5.3.3 Steel mill products prices. The producer price index for steel mill products is compared with the GNP price deflator index in Table 9-13. Steel prices increased at a rate very near the general rate of inflation until 1973. Note that in 1973 the steel index is only four-tenths higher than the GNP index with 1967 = 100. In 1974, however, steel prices increased 26.8 percent over 1973 levels while the implicit price deflator increased only 9.6 percent. Increases in the price of steel continued to outpace inflation through 1979, the last year for which data are available.

This trend, occurring from 1973 to 1979, can in part be attributed to an important basic supply condition. Steel production is energy intensive. OPEC-induced energy price increases beginning in 1974 raised the price of this important input to production, which was in turn reflected in increased real prices of steel.

9.2.5.3.4 Investment in new plant and equipment. In 1967, new capital expenditures in SIC 3312 firms totaled about $1.7 billion. In 1977, new capital expenditures totaled only $1.2 billion in 1967 dollars.[3] In order to determine the significance of this decline, an index has been constructed of new investment by steel firms and is compared with an index of new investment by all industry in Table 9-14.

Real investment in new plant and equipment by all industry increased at a continuously compounded average annual rate of 1.5 percent during the period 1967-1977. Real expenditures by firms in SIC 3312 declined over the same period at an average annual rate of 3.3 percent.

The American Iron and Steel Institute believes the steel industry's poor investment record is due to general economic conditions and government policy and its effects, specifically, high inflation, excessive taxation, and burdensome regulation, which discourage new capital formation.[83] One independent observer, however, blames the poor investment record not on the inability of U.S. steel firms to invest but on their unwillingness to compete with foreign steel by investing in new, lower cost techniques.[84]

9.2.5.3.5 Productivity. Productivity is meant to be a measure of technological advance. The most common measure of productivity is output

TABLE 9-13. STEEL PRICE INDEX AND GNP PRICE DEFLATOR (1967 = 100)[42 79 80]

Year	Steel price index	GNP deflator
1979	280.4	209.1
1978	254.4	192.2
1977	229.9	179.0
1976	209.8	169.2
1975	197.2	160.7
1974	170.0	146.6
1973	134.1	133.7
1972	130.4	126.4
1971	123.0	121.4
1970	114.3	115.5
1969	107.4	109.6
1968	102.5	104.4
1967	100.0	100.0

TABLE 9-14. INDEXES OF REAL NEW INVESTMENT (1967 = 100)[3] [81] [82]

Year	SIC 3312	All industries
1977	72.2	115.9
1976	76.1	108.6
1975	77.4	107.0
1974	67.4	116.9
1973	49.9	113.8
1972	45.7	106.7
1971	49.8	102.1
1970	69.3	105.9
1969	86.4	105.2
1968	67.3	99.1
1967	100.0	100.0

NOTE: Investment expenditures were deflated using the GNP implicit price deflator before indexing.

per employee-hour. Table 9-15 compares this measure for the steel industry with that for all manufacturing for the period 1967-1978. Output per employee-hour increased 28 percent for all manufacturing from 1967 to 1978 while output per employee-hour increased only 21.8 percent for the steel industry.

Increases in labor productivity are often attributed to improvements in capital stock. To the extent it is true that more advanced capital results in greater labor productivity, the relatively slow growth in output per employee-hour in steel is not surprising. As mentioned in Section 9.1.5.3.4, investment in new steel plant and equipment declined in real terms from 1967 to 1977.

9.2.5.3.6 Exports and imports. Much is said about the declining U.S. steel trade balance. There can be little doubt that the domestic industry is losing importance in the world market. Table 9-16 presents data on exports of steel mill products by domestic producers and imports of steel mill products by domestic consumers. During the period 1961-1979, exports of steel mill products changed very little. Exports peaked at 6.4 million Mg in 1970. Over this period imports of steel mill products by domestic consumers increased rapidly, at an average annual rate of 9.5 percent. On balance, the United States was a net importer of steel during the 1960's and 70's. Net exports declined at an average annual rate of 14.1 percent from 1961 to 1979.

9.2.5.4. Projections of Electric Arc Furnace Capacity Additions.

Projecting electric arc furnace capacity additions is complicated by several considerations. These include uncertainties about steel demand in future years, the ability of steel firms to raise capital at an acceptable cost, the rate at which existing capital will be retired, and the relative merits of various competing technologies.

Because projections of capacity additions *per se* are generally unavailable, the first requirement is a projection of domestic steel production. Then, given estimates of the shares of future total production produced by each furnace type as well as capacity utilization rates, capacity projections by furnace type can be estimated.

The projection of domestic raw steel production used in this report is presented in Table 9-17. This projection evidences a continuously com-

TABLE 9-15. INDEX OF OUTPUT PER EMPLOYEE-HOUR (1967 = 100)[85 86 87]

Year	Steel industry	All manufacturing
1978	121.8	128.0
1977	116.0	127.2
1976	114.5	124.2
1975	107.6	121.2
1974	123.5	129.3
1973	123.5	128.3
1972	112.7	121.5
1971	106.2	115.2
1970	101.3	107.9
1969	104.0	107.4
1968	103.5	104.7
1967	100.0	100.0

TABLE 9-16. STEEL MILL PRODUCTS TRADE[28] [41]
(10^3 Mg)

Year	Exports	Imports	Net exports[a]
1979	2,556	15,889	-13,333
1978	2,197	19,169	-16,972
1977	1,817	17,511	-15,694
1976	2,407	12,956	-10,549
1975	2,678	10,895	-8,217
1974	5,291	14,485	-9,194
1973	3,675	13,741	-10,066
1972	2,606	16,037	-13,431
1971	2,564	16,602	-14,038
1970	6,405	12,121	-5,716
1969	4,743	12,729	-7,986
1968	1,968	16,290	-14,322
1967	1,528	10,390	-8,862
1966	1,564	9,753	-8,189
1965	2,264	9,417	-7,153
1964	3,122	5,841	-2,719
1963	2,017	4,940	-2,923
1962	1,826	3,719	-1,893
1961	1,813	2,869	-1,056

[a] Exports minus imports.

TABLE 9-17. PROJECTED DOMESTIC RAW STEEL PRODUCTION, (10^6 Mg)[88]

Year	Production[a]
1990	124.6
1989	122.1
1988	120.9
1987	119.7
1986	119.7
1985	118.5
1984	118.5
1983	118.5
1982	118.5

[a] A. D. Little projection is for finished products assuming the industry meets current environmental requirements. A finished-to-raw yield of 75 percent is assumed for the construction of this table.

pounded growth rate of 0.6 percent per year over the entire 9 years, with the greatest growth in the latter part of the period. Production is projected to increase at a rate of only 0.2 percent per year during 1982-1987.

Domestic raw steel production is projected to total 119.7 million Mg in 1987. Estimates vary on what the share of future total production by electric furnaces will be. In this report, a projected electric arc furnace production share of 31.5 percent for 1987 is used.[89,90] It is thus projected that electric furnaces will produce 37.7 million Mg of raw steel in 1987. Assuming a capacity utilization rate of 85 percent, electric furnace capacity will total 44.4 million Mg in 1987.

It is estimated that electric furnace capacity totaled 39.2 million Mg at year's end 1981.[91,92] If none of the existing electric arc capacity existing in 1981 is retired before 1987, 5.2 million Mg of new electric arc furnace capacity will be added during the period 1982-1987; an annual growth rate of 2.1 percent.

A summary of the electric arc furnace capacity projection for 1987 is presented in Table 9-18. Of the total 5.2 million Mg new electric arc capacity, it is projected that 4.8 million Mg will be met by the construction of carbon steel shops and 0.4 million Mg will be met by the construction of specialty steel shops.[92]

New additions of carbon and specialty capacity are expressed as model plants in this same table. The model plants are those described in Chapter 6. Table 9-18 shows, for example, that the projected 4.8 million Mg of new carbon capacity could be satisfied by the construction of 29 new 90.7-Mg (100 ton) vessel shops of the type represented by model plant 2. The projected 0.4 million Mg of new specialty capacity could be met by the construction of 11 22.7-Mg (25 ton) electric arc furnace/ argon-oxygen decarburization (EAF/AOD) shops.

Projecting the number of each type of model plant that is likely to be built is even more difficult than projecting total capacity additions. The result that follows below from such an effort should be regarded as a scenario as much as a projection.

Examination of characteristics of EAF shops coming on line in 1981 and 1982 reveals that a large proportion of the new shops have a total vessel capacity of about 90.7 Mg; for example, shops with two 36.3-Mg vessels and shops with two 54.4-Mg vessels. Also common but less prominent are shops

TABLE 9-18. SUMMARY OF ELECTRIC ARC FURNACE CAPACITY PROJECTION

1981	Electric Arc Furnace Capacity -	39.2 x 10^6 Mg
1987	Electric Arc Furnace Capacity -	44.4 x 10^6 Mg
1982-1987	New Electric Capacity Additions -	5.2 x 10^6 Mg
1982-1987	New Carbon Steel Shop Capacity -	4.8 x 10^6 Mg
1982-1987	New Specialty Shop Capacity -	0.4 x 10^6 Mg

New Capacity Additions Expressed As Model Plants

Carbon Plants

Model Plant(s)	10^6 Mg Capacity Per Plant	1982-1987 No. of Plants	No. Plants Per Year
1, 6	.03742	128	21
2	.1633	29	5
3, 5	.596	8	1
4	.4348	11	2

Specialty Plants

Model Plant(s)	10^6 Mg Capacity Per Plant	1982-1987 No. of Plants	No. Plants Per Year
7, 8	.03742	11	2
9, 10	.1633	2	<1

with vessel capacity totaling 136.1 Mg and 272.2 Mg.[93] Table 9-19 presents a projection of new plant construction that is fairly consistent with the size distribution of new plants coming on line in 1981 and 1982. Construction of these 19 plants of various sizes would approximately satisfy the projection of 5.2 million Mg of additional electric arc furnace capacity to be built between 1982 and 1987.

The accuracy of a projection can be known with certainty only after the fact. Even at this writing there is some evidence that the projection of 5.2 million Mg of new EAF capacity additions during 1982-1987 is low. At the same time, however, the evidence is conflicting in general and this projection results from a careful synthesis of information from several sources.

9.2.6 Small Business Impacts

The Regulatory Flexibility Act (RFA) requires consideration of proposed regulations on small "entities." This section briefly examines the applicability of the RFA to the proposed NSPS on EAF shops.

The guidelines for conducting a regulatory flexibility analysis define a small business as "any business concern which is independently owned and operated and not dominant in its field as defined by the Small Business Administration Regulations under Section 3 of the Small Business Act." The Small Business Administration has determined that any firm classified in SIC 3312 that employs less than 1,000 workers will be considered small in regard to the Small Business Act.

RFA guidelines clearly focus on regulations that apply to existing rather than new sources. It is seldom possible to determine which individual firms will construct new sources and thus be affected by the NSPS. In the case of an NSPS on new electric arc steel plants, this problem is very relevant. First, plants may be constructed in the future by firms that are not currently involved in electric arc steelmaking or, for that matter, in any manner of steelmaking. The employment of such unknown potential producers can not be known. Second, even assuming that the only firms that will build EAF plants in the future are those firms that currently operate such plants, it does not logically follow that all or even some of the new plants will be built by the existing small firms. It is quite possible, however, that some of the projected new EAF plants will be constructed by small firms.

TABLE 9-19. PROJECTED CONSTRUCTION OF ELECTRIC FURNACE PLANTS, 1982-1987

Carbon Steel Model Plant	No. of Plants	10^6 Mg Total Annual Capacity
Model Plant 2--one 90.7-Mg EAF	8	1.3
Model Plant 4--one 136.1-Mg UHP EAF	5	2.2
Model Plant 3--one 272.2-Mg EAF	2	1.2
TOTAL	15	4.7

Specialty Steel Model Plant	No. of Plants	10^6 Mg Total Annual Capacity
Model Plants 7,8 --22.7-Mg EAF/AOD	2	0.07
Model Plants 9,10--90.7-Mg EAF/AOD	2	0.33
TOTAL	4	0.40

Of the 80 firms that currently operate one or more EAF shops, employment and financial data are available for only 42. Of these 42, none employ fewer than 1,000 employees. It is quite likely, however, that some of the remaining 38 firms do qualify as small entities. If it is assumed that all of these 38 firms are small, the number of small firms that would have to be affected by the regulation to constitute a "substantial" number is 20 percent of these 38, or 7 firms. Because it is projected that anywhere from 10 to over 100 new EAF plants will be built by 1987, it is possible that a substantial number of small firms will be affected by the regulation.

Once it has been determined that a substantial number of small entities may be affected by a regulation, the RFA requires a determination of whether these impacts are "significant." The degree of economic impact that a regulation will have on any firm building an electric arc furnace plant will depend in part on the type of plant it builds. In general, the "significance" of the impact of each proposed NSPS as measured by RFA criteria is greater for smaller EAF plants than for larger ones. It is not, however, logical to presume that small entities will construct small EAF plants. To test the hypothesis that small firms tend to build small plants, a correlation analysis was conducted using the data on employment and plant size that is available for the 42 firms mentioned above. EAF vessel capacity, the major determinant of annual steel capacity, was used as a proxy for plant size. When a firm had one or more plants and a total of two or more vessels, an average vessel capacity was used.

The null hypothesis that firm employment and average vessel capacity are not correlated can not be rejected at any reasonable level of significance. The Pearson correlation coefficient for a sample of this size at a 5 percent level of significance is approximately 0.304. The coefficient of correlation between employment and average vessel capacity for the sample tested is 0.07. There is thus no significant support for the hypothesis that small firms build small plants.

A second statistical test involved comparing the average vessel size for the 42 firms known to be "large" with the average vessel size for the 38 firms assumed to be small. The average vessel size for large firms is 78 Mg. The average vessel size for small firms is 58 Mg. Whether or not the 20 Mg difference between vessels of large and small firms is significant can be tested using a t-test for the difference between the means from two samples. Using such a test, the calculated t-statistic for this problem is 1.43. In order for the difference between means to be significant for a sample of this size at a 10 percent significance level, the t-statistic must exceed 1.67. This test lends little support to the notion the small firms build small plants.

Despite the statistical evidence to the contrary cited above, the investigation of the possible need to conduct a regulatory flexibility analysis will continue on the premise that small firms will construct small electric arc furnace plants. The RFA next requires an evaluation of whether the economic impact of the proposed standards on small entities will be "significant" as measured by several criteria. This evaluation follows below.

The impact of a regulation on a small entity is judged to be significant if the regulation causes the average total cost of production to increase by 5 percent or more. The average total cost impacts reported in Table 9-20 indicate that neither regulatory alternative 2 or 3 causes an increase in ATC from baseline alternative 1 as high as 5 percent for any model plant. The most severe impact is 0.31 percent, for model plant 7 under regulatory alternative 3. It can thus be safely concluded that the impacts are not "significant" from an average total cost standpoint.

The second criteria that renders an alternative's impact "significant" relates compliance costs to sales for small versus large entities. If compliance costs as a percent of sales for small entities is at least 10 percentage points higher than compliance costs as a percent of sales for large entities, the impact is judged to be significant.

It is unclear whether "sales" refer to total sales by the entity (firm) or total sales by the affected facility. Since firm sales data are unavailable for many of the companies, total plant sales are used. The 1981 market price of carbon or specialty steel billets is multiplied by each plant's estimated annual output of billets to arrive at an estimate of each plant's annual sales. The total annualized cost of compliance for each plant under each alternative is expressed as a percent of its own annual sales in Table 9-21.

The total annualized cost of compliance as a percent of sales is generally higher for small plants than for large plants. The differences,

TABLE 9-20. AVERAGE TOTAL COST IMPACTS ASSUMING 6.2 PERCENT WEIGHTED AVERAGE COST OF CAPITAL (1981 $/Mg)

	Regulatory Impact From Baseline[a]					
	Regulatory Alternative					
Model	1		2		3	
Plant	1981$	percent	1981$	percent	1981$	percent
1	19.13	6.35	0.14	0.04	0.59	0.18
1[b]	19.13	6.35	na	na	-0.64	-0.20
2	12.17	5.49	0.22	0.09	0.37	0.16
3	5.06	2.72	0.14	0.07	0.50	0.26
4	7.38	3.73	0.12	0.06	0.30	0.15
5	5.32	2.91	0.15	0.08	0.53	0.28
6	20.26	7.12	0.16	0.05	0.62	0.20
6[b]	20.26	7.12	na	na	-0.68	-0.22
7	36.27	5.70	0.81	0.12	2.09	0.31
8	31.00	4.87	0.22	0.03	1.06	0.16
9	22.17	4.23	0.36	0.07	1.08	0.20
10	20.83	3.97	0.22	0.04	1.04	0.19

[a] Impact of baseline regulatory alternative 1 is measured from no control.

[b] Total Furnace Enclosure Option

NOTE: na = not applicable.

TABLE 9-21. TOTAL ANNUALIZED COST OF COMPLIANCE ABOVE BASELINE AS A PERCENT OF ANNUAL PLANT SALES

Model Plant	Regulatory Alternative	
	2	3
1	0.02	0.11
1[a]	NA	-0.15
2	0.04	0.07
3	0.03	0.10
4	0.02	0.59
5	0.03	0.11
6	0.02	0.12
6[a]	NA	-0.15
7	0.10	0.25
8	0.02	0.12
9	0.04	0.12
10	0.02	0.11

[a] Total furnace enclosure option.

however, are not great. The total annualized cost of compliance as a percent of sales is never as much as one-half of one percentage point greater for a small plant than for a large one. The small business impact of these alternatives is certainly not significant by this measure.

A third criterion to measure the significance of an impact on small firms compares the capital cost of compliance with the capital available to small firms. It is extremely difficult, if at all possible, to determine how much capital is available to a firm. With financial data on small firms unavailable, the problem is magnified.

A reasonable approach is to recognize that the capital available to a small firm building a new EAF plant at least equals the capital cost of the plant itself. The capital cost of compliance with each proposed regulatory alternative expressed as a percent of the capital cost of the plant itself is presented for each plant in Table 9-22. The capital cost of compliance with regulatory alternative 2 is well under two percent of plant capital cost for all model plants. For regulatory alternative 3, the greatest compliance capital cost as a percent of plant cost is 3.68 percent (model plant 5).

It is the conclusion of this examination that capital costs of compliance do not represent a "significant" portion of capital available to small entities.

A regulation is considered to have a significant impact on small entities if it is likely to result in closures of small entities. It is quite safe to conclude that the imposition of a New Source Performance Standard on electric arc steelmaking will result in no closures of firms of any size. Indeed, a more likely effect is an extension of the economic life of existing firms by raising the market price of their output, steel, while not increasing their costs of production (see Section 9.2.6).

Considering all of the significance criteria, it is concluded that the proposed standards would not have a significant impact on small entities. Average total cost impacts are all under one-half of one percent. Total annualized cost of compliance as a percent of sales is not significantly higher for small plants than for large plants. Capital costs of compliance relative to plant costs are all quite small, and the standards are unlikely to result in closures of small firms. Because anticipated impacts on small

TABLE 9-22. COMPLIANCE CAPITAL COST ABOVE BASELINE AS A PERCENT OF BASELINE PLANT CAPITAL COST

Model Plant	Regulatory Alternative	
	2	3
1	0.57	0.92
1[a]	NA	-0.23
2	0.62	1.03
3	0.98	2.30
4	0.48	0.96
5	1.58	3.68
6	0.91	1.37
6[a]	NA	-0.46
7	0.33	0.99
8	0.34	0.75
9	0.32	0.94
10	0.27	1.03

[a] Total furnace enclosure option.

entities are insignificant by all measures, a Regulatory Flexibility Analysis is not conducted for these standards.

9.3 ECONOMIC IMPACTS OF REGULATORY ALTERNATIVES

This section presents the estimated impacts of the regulatory alternatives for electric arc process steel plants. As described in Chapter 6, 10 types of model plants are used to represent typical EAF and EAF/AOD facilities that might be constructed by the industry in the future.

Three regulatory alternatives are considered. Regulatory alternative 1 is the baseline case from which impacts of the two proposed, increasingly more stringent alternatives are measured.

Section 9.2.1 summarizes the range of estimated maximum impacts that could result from the NSPS alternatives and presents anticipated impact estimates. Section 9.2.2 presents the theoretical model of discounted cash flows employed to compute both net present value and price impacts. Section 9.2.3 presents the full range of maximum impacts on project net present value assuming full cost absorption, and the full range of maximum price impacts assuming full cost pass-through. Section 9.2.4 employs a refined model to compute a single set of price impacts and associated output, employment, and import impacts for each alternative. The issue of capital availability is addressed in Section 9.2.5. Section 9.2.6 presents estimates of maximum total costs of industry compliance.

9.3.1 Summary

Control of fugitive emissions under regulatory alternative 2 or 3 imposes additional capital costs on the construction of an EAF project and increases its annual operating cost. It is estimated that regulatory alternative 2 would increase the cost of producing semifinished carbon steel by between \$0.12 and \$0.22 per Mg (\$0.11-\$0.20 per ton). These changes represent impacts of from 0.04 to 0.09 percent. The impact of alternative 2 on the cost of producing specialty steel is estimated to range from \$0.22 to \$0.81 per Mg (\$0.20 to \$0.74 per ton). These impacts are betweeen 0.03 and 0.12 percent.

It is estimated that under regulatory alternative 3, cost impacts could vary from \$-0.68 to \$0.62 per Mg (\$-0.62 to \$0.56 per ton) for carbon steel and from \$1.04 to \$2.09 per Mg (\$0.95 to \$1.90 per ton) for specialty steel. These impacts are all less than 0.32 percent.

Assuming that producers pass all increases in production costs on to consumers, the increases in production costs would cause corresponding impacts on 1987 steel prices. These estimated price impacts could in turn lead to impacts on 1987 domestic steel output, industry employment, and steel imports. These impacts are presented in Section 9.2.3.

The economic impacts that would actually result from the NSPS depend on which projects are pursued by industry participants and the supply and demand conditions prevalent in the market. The conclusion of this analysis, which is based on the premise that model plants 4 and 7 most closely typify future EAF and EAF/AOD construction, is that impacts would occur as increases in steel prices, reductions in industry employment opportunities, and increases in steel imports.

It is estimated that the price of semifinished carbon steel would be $0.12 per Mg ($0.11 per ton) higher in 1987 under alternative 2 than it would be under baseline alternative 1. The impact on the price of specialty steel is an estimated $0.81 per Mg ($0.74 per ton). These price increases represent impacts of 0.06 percent and 0.12 percent respectively.

Steel users might purchase less domestic steel and more foreign steel in 1987 as a result of the increases in domestic steel prices. Domestic steel shipments would be down an estimated 150,000 Mg (165,000 tons) under alternative 2--an impact of 0.13 percent. Imports could be approximately 19,000 Mg (21,000 tons) greater--an impact of 0.09 percent. The impact on domestic steel production would cause a reduction in employment opportunities of about 0.12 percent, or about 542 jobs, in 1987. The estimated total cost of regulatory alternative 2 in 1987 is $1.381 million.

It is estimated that regulatory alternative 3 would raise the price of semifinished carbon steel by $0.30 per Mg ($0.27 per ton) above its baseline 1987 price. The anticipated impact on the price of specialty steel of alternative 3 is $2.09 per Mg ($1.90 per ton). These price increases represent impacts of 0.15 percent and 0.31 percent, respectively.

Domestic steel shipments would be down an estimated 370,000 Mg (407,000 tons) in 1987 under regulatory alternative 3--an impact of 0.31 percent from baseline. This impact on domestic steel production would cause a proportionate decrease in 1987 employment opportunities, about 1,387 jobs. Steel imports in 1987 would be approximately 40,000 Mg (44,000 tons) higher under alternative 3 than under regulatory alternative 1--an impact of 0.20 percent. The estimated total cost of regulatory alternative 3 in 1987 is $2.575 million.

Electric arc steel making is apparently a profitable activity. This is indicated by two kinds of evidence. First, construction of new EAF facilities and the replacement of older steel making technologies by EAF shops is brisk. This indicates that the industry itself views EAF steel making as profitable. Second, the engineering cost data for the 10 model facilities examined in this study suggest strongly that steel can be produced at an average total cost significantly below market price. In light of this observation, it seems unlikely that the industry impacts reported above would significantly affect the future growth of electric steel making.

9.3.2 Methodology

9.3.2.1 The Discounted Cash Flows Approach. The economic impacts of New Source Performance Standards on electric arc process furnaces are estimated using a discounted cash flows (DCF) analysis. Under this approach, the expected future annual net revenue flows generated by an investment in an electric arc furnace project are discounted at an appropriate interest rate and summed to determine the net present value of the project. This section describes the DCF theory and methodology in some detail.

An investment is expected to generate a series of cash inflows and outflows during its lifetime. The net cash flow in the first year (year zero) is negative as the cash outflows of the initial investment are not offset by any cash inflows. After the project begins production, it will generate a stream of cash inflows in the form of revenues from the sale of its output and depreciation of the capital equipment, and cash outflows in the form of operating expenses. Beginning with year one and continuing throughout the lifetime of the project, annual cash flows are expected to be positive, but need not be. Although cash inflows and outflows may occur at any time, it is assumed that they will take place at the end of the year. It is also assumed that the only investment in the project takes place at the end of year zero and is followed by a series of net cash inflows. These assumptions guarantee a unique rate of return for each project.[94]

The cash outflow in the first year may be expressed:

$$Y_o = (FCC + WC) - (TCRED \cdot FCC) \tag{9-1}$$

where FCC is the principal value of the capital investment, WC is the value of the working capital and TCRED is the percentage of the capital investment resulting in a direct tax savings, or tax credit, to the firm.

The project generates its first revenues at the end of its first year of production (year two). The net cash flows in this and succeeding years can be expressed:

$$Y_t = (R_t - E_t)\ (1 - T) + D_t T \qquad t = 1, \ldots, N\ . \tag{9-2}$$

The first term in equation (9-2) represents the net after-tax inflows of the project generated by the sales of the output. Total revenues in year t can be expressed:

$$R_t = (P \cdot Q)_t \tag{9-3}$$

where P is the per-unit price of output and Q is the quantity of output sold during the year. Total operating costs in year t can be expressed:

$$E_t = ((V \cdot Q) + F)_t \tag{9-4}$$

where V is the per-unit variable cost of production and F is the fixed annual cost of operating the project. Variable costs include expenditures on material inputs, labor and energy. Fixed costs include such expenses as site rent (explicit or implicit), insurance, and administrative overhead.

Only net revenues are subject to corporate income taxes (T). Thus, annual total operating cost is deducted from total revenue to yield the taxable net revenue. The firm's after-tax net revenue in year t is thus the first term in equation (9-2).

Federal income tax laws allow a deduction for depreciation of the capital equipment. This deduction reduces income tax payments and is thus treated as a cash inflow in the second term in equation (9-2). In this analysis, the straight-line method of capital depreciation is assumed. Thus,

$$D_t T = (FCC/N) \cdot T \tag{9-5}$$

where N is the project life in years. The salvage value of the plant is assumed to be zero.

The net cash flows represented by equation (9-2) occur at the end of the first through the Nth years, where N is the life of the project. An additional cash inflow actually occurs at the end of the Nth year when the working capital, WC in equation (9-1), is recovered at the end of the project. This inflow is in fact accounted for in the analysis.

The investment project is thus represented as a cash outflow in the first year followed by N cash inflows and outflows in successive years. Cash flows that occur over a future period must be discounted by an appropriate interest rate to reflect the fact that a sum of money received at some future date is worth less than an equal sum received today. The discounted value of this sum received in the future is called its present value. The discount factor is a function of both time and the interest rate, and can be expressed as:

$$DF_t = (1 + r)^{-t} \qquad (9\text{-}6)$$

where DF is the discount factor for year t and r is the interest rate.

An understanding of the discount factor and the selection of an appropriate rate of interest in practice is important. The interest rate r in equation (9-6) can be viewed as the cost to the firm of acquiring funds for the project. The firm can acquire funds in essentially any combination of three ways. It can issue bonds, sell stock, or utilize currently held liquid assets. There is a cost associated with each method. Interest must be paid on bonds, dividends on stock, and there is an opportunity cost associated with utilizing internal funds. In the absence of specific information on how a project would be financed, a weighted average cost of capital can be used.

The sum of the discounted cash flows from a project over its life is the net present value (NPV) of the project. The NPV of a project can be expressed most simply as:

$$NPV = \sum_{t=1}^{N} (Y_t \cdot DF_t) - Y_o \qquad (9\text{-}7)$$

where all terms are as defined above. The net present value of a project is thus the sum of the discounted after-tax net revenues minus the initial capital expenditure.

As discussed previously, the objective of a firm is to maximize shareholders' wealth. This is accomplished by maximizing the discounted stream of cash flows to the firm. The NPV of an investment is in fact the discounted value of cash flows from the project available as dividends payable to stockholders. Thus, the objective of the firm is to invest in any project with a positive NPV or, where funds are limited, to invest in the project with the highest positive NPV.[95,96] Equation (9-7) can be used to calculate the net present value of each plant under any given regulatory alternative and to evaluate each plant type according to the decision criterion.

In Section 9.1.4.4 it is concluded that recent pricing behavior in the domestic steel industry does not strongly support either a monopoly or an oligopoly market structure. Increasingly, steel prices appear to be more the result of underlying supply and demand conditions than the result of price-setting behavior of any market participant. Thus, in this analysis, competitive conditions are assumed to prevail. In particular, firms are assumed to be price takers.

In this analysis, two types of impacts that could result from the proposed NSPS on EAF facilities are estimated. Equation (9-7) is utilized as stated to estimate the NPV of each project under each regulatory alternative. A different form of the same equation is used to estimate the average total cost of EAF steel production for each plant under each regulatory alternative. This estimate is used in a discussion of steel price impacts.

9.3.2.2 Net Present Value Impact Methodology. In general, an NSPS increases average total cost (ATC) of production. This can result from additional capital costs for pollution control equipment, increased operating costs, or both. If market demand for the project is perfectly elastic, a situation of full cost absorption prevails--the increase in ATC cannot be passed forward in the form of increased product price. ATC is an expense deducted from gross revenue in equation (9-7). Thus, the NSPS will reduce the NPV of a project if unit price remains unchanged. In a full cost absorption situation, the effect of an NSPS is to reduce the present value of dividends payable to stockholders.

The nature of the NPV impact on a given stockholder depends on whether the stock was purchased before or after the impact was perceived by the market as a whole. The recipients of the loss in NPV are the owners of stock at the time the loss information becomes known. Once it is perceived that the increased ATC resulting from the NSPS will reduce future net income streams, prices of outstanding stock decline until the new, lower present value of the dividends yields the same rate of return available on other shares of stock.[97] Holders of outstanding stock at the time this price adjustment occurs suffer a one-time wealth loss.

Once stock prices have adjusted downward, the dividend payments yield the same rate of return on these shares as dividend payments on totally unaffected stocks yield. The holders of NSPS affected stock at the time the information is learned receive this same market rate of return on their new, lower priced stock. Moreover, investors who purchase EAF steel firm stock after the market has accounted for the NSPS impact suffer neither a loss in wealth nor a loss in their rate of return. The lower price they pay for stock compensates them for the lower dividend payments they anticipate.

In this analysis, equation (9-7) is utilized to calculate NPV impacts resulting from the proposed regulatory alternatives. The net present values of the 10 model plants under regulatory alternatives 1, 2, and 3, are compared to the NPV's of these same plants with no fugutive emissions control. The loss in NPV occurring as a result of the NSPS under a situation of full cost absorption is interpreted as the impact on stockholders' wealth.

9.3.2.3 Steel Price Impact Methodology. An increase in the ATC of EAF steel will be exactly reflected in higher prices in a market with perfectly elastic supply or perfectly inelastic demand.

Price impacts of the three regulatory alternatives are calculated assuming that the price change is exactly equal to the change in ATC. This change in ATC is in turn calculated using a revised form of equation (9-7), derived below. In a market situation where price equals average total cost, the NPV of a project is equal to zero. That is, dividend payments in excess of those required to raise capital for the project, which themselves yield the rate r in equation (9-6), are zero. When equation (9-2) is substituted into (9-7) and (9-7) is set equal to zero, (9-7) can be written:

$$\sum_{t=1}^{N} [(R_t - E_t)(1 - T) + D_t T] \, DF_t = Y_o \, . \tag{9-8}$$

If revenues and expenses are the same over all periods, equation (9-8) can be written

$$(R - E)\,(1 - T) \sum_{t=1}^{N} DF_t + \sum_{t=1}^{N} D_t T DF_t = Y_o \tag{9-9}$$

recognizing that (1 - T) is a constant. The sum of the discount factors as t ranges from 1 to N can be written:

$$F = \sum_{t=1}^{N} DF_t = [1 - (1 + r)^{-N}]/r \, . \tag{9-10}$$

Substituting equations (9-5) and (9-10) into (9-9) yields:

$$(R - E)\,(1 - T)\,F + (FCC/N) \cdot T \cdot F = Y_o \, . \tag{9-11}$$

Substituting equations (9-3) and (9-1) into (9-11) and rearranging further yields:

$$(P \cdot Q) - E = \frac{(FCC + WC) - (TCRED \cdot FCC) - DSL}{(1 - T) \cdot F} \tag{9-12}$$

where DSL = (FCC/N) · T · F, and represents the present value of the tax savings due to straight-line depreciation of the fixed capital.

Finally, Q and E can be moved to the right-hand side of (9-12) to yield:

$$P = \frac{(FCC + WC) - (TCRED \cdot FCC) - DSL}{(1 - T)\,F \cdot Q} + \frac{E}{Q} \, . \tag{9-13}$$

Where P = ATC, equation (9-13) calculates average total cost. The first term in (9-13) is capital cost per unit including allowances for the tax credit and depreciation, and the second term is operating cost per unit.

The cost per megagram of EAF steel is calculated using equation (9-13) for each model project uncontrolled and under each regulatory alternative. Price impacts are estimated assuming that any additional cost resulting from a proposed NSPS is passed forward in a higher price.

In Section 9.2.3, maximum impacts on net present value, price, and other relevant variables are presented for all plants under each regulatory alternative. In 9.2.4, an assessment is made of actual expected impacts based on a somewhat refined model and certain simplifying assumptions.

9.3.3 Economic Impacts of Regulatory Alternatives

This section presents ranges of maximum impact estimates for the regulatory alternatives. Maximum impacts on net present value are presented for the case of full cost absorption. The presented range of impacts on steel prices, output, employment, and imports results from a situation of full cost pricing (full cost pass-through to consumers).

Table 9-23 contains cost data in 1981 dollars for each model plant uncontrolled and under each regulatory alternative. The annual operating costs include an estimate for the value of scrap used by the steel furnace equivalent to \$94.16 per Mg (1981 dollars) of scrap used in carbon shops and \$273.72 per Mg (1981 dollars) of scrap used in specialty shops.[98] A steel/scrap yield of 85 percent is assumed. Unlike the annualized costs in Table 8-1, the annual operating costs in Table 9-23 do not include a capital recovery allowance. Capital costs in Table 9-23 are employed in the FCC term of equation (9-1) while annual operating costs are employed in the E term in equation (9-4).

Table 9-24 lists the parameter values actually employed to compute NPV and ATC. A value of working capital equal to 50 percent of the value of the fixed capital is assumed. The average working capital-to-fixed asset ratio for steel firms is 83 percent.[76] However, it is believed that this average ratio is probably too high for an incremental investment, and a 50 percent ratio has been arbitrarily selected. Currently, the investment tax credit is 10 percent of the capital cost. The federal and average state marginal corporate tax rates are 46 percent and 6 percent, respectively.[99] Since state taxes are deductible from taxable income for federal tax purposes, the overall effective tax rate is 49 percent. The capital budgeting decision is based on an expected economic project life of 15 years. Two separate interest rates are employed. The weighted average cost of capital to the steel industry has been estimated to be 6.2 percent.[100] An alternative interest rate of 10 percent is employed to investigate the sensitivity of the estimate to this parameter. The steel prices used are Bureau of Labor Statistics estimates for steel billets.[98]

TABLE 9-23. MODEL PLANT COST DATA
(10^6 1981 $)

	Regulatory Alternative							
	No Control		1		2		3	
Model Plant	Capital Cost	Annual[b] Operating Cost	Capital Cost	Annual[b] Operating Cost	Capital Cost	Annual[b] Operating Cost	Capital Cost	Annual[b] Operating Cost
1	7.00	7.980	8.73	8.253	8.78	8.249	8.81	8.257
1[a]							8.71	8.224
2	20.00	26.070	24.37	26.907	24.52	26.909	24.62	27.779
3	25.60	86.430	30.47	88.020	30.77	88.033	31.17	88.139
4	33.20	64.430	39.49	65.920	39.68	65.927	39.87	65.957
5	17.00	86.060	22.84	87.599	23.20	87.606	23.68	87.707
6	4.50	7.910	6.58	8.155	6.64	8.149	6.67	8.157
6[a]							6.55	8.148
7	14.60	16.880	18.19	17.342	18.25	17.356	18.37	17.373
8	14.60	16.880	17.44	17.316	17.50	17.312	17.57	17.325
9	44.00	62.210	53.28	63.496	53.45	63.513	53.78	63.549
10	44.00	62.210	52.45	63.467	52.59	63.470	52.99	63.508

[a] Total Furnace Enclosure Option

[b] Does Not Include Capital Recovery

TABLE 9-24. MODEL PARAMETER VALUES[76,98,99,100]

Parameter	Value
Working capital (WC)	0.5 x FCC
Federal investment tax credit (TCRED)	0.1 x FCC
Federal corporate tax rate (FT)	46 percent
State corporate tax rate (ST)	6 percent
Project life (N)	15 years
Interest rate (r)	6.2 percent and 10.0 percent
Steel price (P)	\$412.16 per Mg--carbon \$715.18 per Mg--specialty

If the recent past is any indicator of things to come, the general price level will rise each year through the future. This continual increase in the overall level of prices is called inflation. During a period of inflation, some prices rise more rapidly than others while the prices of some goods actually decline. The change in the price of an individual good is called its nominal price change. The change in the price of an individual good relative to the rate of inflation is called its real price change. If the rate of inflation is 10 percent and the nominal price of, for example, a ton of steel increases by 12 percent, the real price of steel has increased only 2 percent. It should be clear then that nominal prices tend to be less stable than real prices.

Historically, real prices of individual goods have risen far more slowly than nominal prices. Referring back to Table 9-13 in section 9.1, nominal steel prices have increased at an average annual rate of 8.6 percent while real steel prices have increased at an average annual rate of only 2.5 percent. This difference is attributed to a rate of inflation of 6.1 percent over the same period.

Project net present values depend in large part on future cash flows, which in turn depend on prices received for output and prices paid for inputs. Historically, the real price for a particular product has tended to change similarly with the weighted average of the real prices of its various inputs. For this reason, net present value calculations in real terms are little different when they are calculated using projected nominal cash flows than when they are calculated assuming constant real prices for inputs and output. In this analysis, an assumption of constant real prices for both inputs and outputs is made.

A second important factor in net present value calculations is the discount rate. This parameter is perversely affected by the rate of inflation, with implications for net present value computation. Again, an important distinction must be made between nominal and real values. The nominal rate of interest is comprised of a real rate of interest plus an inflation premium. The inflation premium is intended to compensate the lender for the fact that a dollar he receives in repayment is worth less than a dollar he initially lent. In periods of significant inflation, nominal interest rates, which are what we commonly hear quoted in the media, are considerably higher than real interest rates. Because future cash flows are assumed to remain constant in real terms, as described above, the net present value computation should incorporate a real discount rate. The 6.2 percent and 10.0 percent discount rates used in this analysis are real discount rates, which explains why they appear low relative to current market rates, which are expressed in nominal terms.

An alternative methodology would be to employ nominal values for both cash flows and discount rates, but the net present value result would be little changed. While inflated cash flows would increase the nominal net present value, the higher nominal discount rate would offset this effect, yielding a very similar net present value estimate.

9.3.3.1 Net Present Value Impacts. Recall that the NPV of a project is the discounted present value of total revenue minus total costs over the life of the project, where total costs include capital recovery. The project NPV is equivalent to stockholders' wealth attributable to the project.

The NPV of each model project under each regulatory alternative is presented in Table 9-25. All 10 EAF shops modeled yield positive NPV's under all regulatory alternatives. Larger shops generally yield higher NPV's. This is attributable to apparent plant economies of scale, to be discussed in Section 9.2.3.2.

It is evident from Table 9-25 that plant NPV's become lower as regulatory alternatives become more stringent. The reason for this is simple: assuming no price changes, the control of secondary emissions imposes additional capital and operating costs while leaving the value of the marketable output, and hence revenues, unchanged. It must be remembered, however, that the controlled plants yield an additional output--reduced emissions.

There is one apparent exception to the rule that more stringent controls result in lower NPV's. Model plants 1 and 6 yield higher NPV's under alternative 3 than at baseline when they are controlled with total furnace enclosures. This is the result of the lower operating costs associated with this control option.

Uncontrolled carbon shop (model plants 1, 2, 3, 4, 5 and 6) NPV's range from a low of $16.524 million to a high of $546.409 million. When these same plants are required to meet baseline alternative 1, NPV's range

TABLE 9-25. PROJECT NET PRESENT VALUES ASSUMING 6.2 PERCENT WEIGHTED AVERAGE COST OF CAPITAL (10^6 1981 $)

Model Plant	No Control	Regulatory Alternative 1 (Baseline)	2	3
1	16.524	13.667	13.646	13.579
1[a]	16.524	13.667	na	13.762
2	124.064	116.134	115.993	115.890
3	537.019	524.984	524.658	523.789
4	372.263	359.463	359.261	358.947
5	546.409	533.767	533.417	532.502
6	19.070	16.045	16.021	15.952
6[a]	19.070	16.045	na	16.146
7	11.747	6.332	6.211	6.020
8	11.747	7.119	7.086	6.962
9	124.477	110.032	109.796	109.322
10	124.477	110.905	110.765	110.230

[a] Total Furnace Enclosure Option

NOTE: na = not applicable.

from $13.667 million to $533.767 million. Under proposed alternative 2, NPV's range from $13.646 million to $533.417 million. The range of NPV's for alternative 3 is $13.579 million to $532.502 million.

Uncontrolled specialty steel shop (model plants 7, 8, 9 and 10) NPV's range from $11.747 million to $124.477 million. When these same plants are required to meet baseline alternative 1, NPV's range between $6.332 million and $110.905 million. Under proposed alternative 2, NPV's are between $6.211 million and $110.765 million. Under regulatory alternative 3 specialty shop NPV's are between $6.020 million and $110.230 million.

Table 9-26 presents the maximum changes in NPV that could occur from the various regulatory alternatives. The loss in NPV should be interpreted as the reduction in wealth that affected stockholders would experience. The impact would be felt as a one-time reduction in affected stock prices.

Moving from no control to baseline alternative 1 results in NPV losses between $2.86 million and $12.80 million for carbon shops and between $4.63 million and $14.44 million for specialty shops. These losses represent changes from no control of as little as 2.24 percent for model plant 3 to as high as 46.09 percent for model plant 7.

Both carbon and specialty EAF steel plant NPV's are little different from baseline (regulatory alternative 1) in absolute terms under alternative 2 and 3. The largest NPV change from baseline is the $1.26 million reduction experienced by model plant 5 under regulatory alternative 3. As indicated in Table 9-26, some plant NPV's actually increase under the more stringent controls due to reductions in operating costs of total furnace enclosures and reductions in capital costs of common control devices.

Net present value impacts from baseline are also modest in percentage terms. In no case does a plant's NPV change by more than 5 percent, and reductions of less than 1 percent are indicated for most shops.

Tables 9-27 and 9-28 present analogous NPV impacts using a weighted average cost of capital of 10.0 percent. Note that in all cases project NPV is lower than when a weighted average cost of capital of 6.2 percent is employed. This is because the present value of future net revenues declines as the cost of capital rises. However, neither the magnitude changes nor the percentage changes are significantly different when a weighted average

TABLE 9-26. NET PRESENT VALUE IMPACTS ASSUMING 6.2 PERCENT WEIGHTED AVERAGE COST OF CAPITAL

Model Plant	Regulatory Impact From Baseline[a] — Regulatory Alternative 1: 10^6 1981$	1: percent	2: 10^6 1981$	2: percent	3: 10^6 1981$	3: percent
1	-2.86	-17.29	-0.02	-0.16	-0.09	-0.64
1[b]	-2.86	-17.29	na	na	0.10	0.70
2	-7.93	-6.39	-0.14	-0.12	-0.24	-0.21
3	-12.04	-2.24	-0.33	-0.06	-1.20	-0.23
4	-12.80	-3.44	-0.20	-0.06	-0.52	-0.14
5	-12.64	-2.31	-0.35	-0.07	-1.26	-0.24
6	-3.03	-15.86	-0.02	-0.15	-0.09	-0.58
6[b]	-3.03	-15.86	na	na	0.10	0.63
7	-5.41	-46.09	-0.12	-1.91	-0.31	-4.94
8	-4.63	-39.39	-0.03	-0.46	-0.16	-2.21
9	-14.44	-11.60	-0.24	-0.21	-0.70	-0.64
10	-13.57	-10.90	-0.14	-0.13	-0.68	-0.61

[a] Impact of baseline regulatory alternative 1 is measured from no control.

[b] Total Furnace Enclosure Option

NOTE: na = not applicable.

TABLE 9-27. PROJECT NET PRESENT VALUES ASSUMING
10.0 PERCENT WEIGHTED AVERAGE COST OF CAPITAL
(10^6 1981 $)

		Regulatory Alternative		
Model Plant	No Control	1 (Baseline)	2	3
1	10.797	7.959	7.925	7.862
1[a]	10.797	7.959	na	8.041
2	91.825	84.089	83.928	83.814
3	417.617	406.458	406.101	405.279
4	284.386	272.152	271.929	271.617
5	427.908	415.948	415.551	414.667
6	13.644	10.556	10.517	10.453
6[a]	13.644	10.556	na	10.646
7	4.496	-0.987	-1.103	-1.294
8	4.496	-0.114	-0.161	-0.282
9	84.222	69.694	69.451	68.973
10	84.222	70.661	70.504	69.947

[a] Total Furnace Enclosure Option

NOTE: na = not applicable.

TABLE 9-28. NET PRESENT VALUE IMPACTS ASSUMING 10.0 PERCENT WEIGHTED AVERAGE COST OF CAPITAL

	Regulatory Impact From Baseline[a]					
	Regulatory Alternative					
	1		2		3	
Model Plant	10^6 1981$	percent	10^6 1981$	percent	10^6 1981$	percent
1	-2.84	-26.29	-0.03	-0.42	-0.10	-1.21
1[b]	-2.84	-26.29	na	na	0.08	1.03
2	-7.74	-8.42	-0.16	-0.19	-0.28	-0.32
3	-11.16	-2.67	-0.36	-0.09	-1.18	-0.29
4	-12.23	-4.30	-0.22	-0.08	-0.53	-0.20
5	-11.96	-2.80	-0.40	-0.10	-1.28	-0.31
6	-3.09	-22.63	-0.04	-0.37	-0.10	-0.98
6[b]	-3.09	-22.63	na	na	0.09	0.85
7	-5.48	-121.95	-0.12	11.75	-0.31	31.18
8	-4.61	-102.55	-0.05	40.17	-0.17	146.64
9	-14.53	-17.25	-0.24	-0.35	-0.72	-1.03
10	-13.56	-16.10	-0.16	-0.22	-0.71	-1.01

[a] Impact of baseline regulatory alternative 1 is measured from no control.

[b] Total Furnace Enclosure Option

NOTE: na = not applicable.

cost of capital of 10.0 percent is used. Note that the NPV's of model plants 7 and 8 are negative under each control option when a weighted average cost of capital of 10 percent is employed.

To reiterate, these estimated changes in NPV are maximum impacts. They occur only in the extreme case of full cost absorption. The other extreme, the case of full cost pass through, is examined in Section 9.2.3.2.

9.3.3.2 Steel Cost Impacts. The purpose of this section is to present NSPS impacts on the average total cost of producing steel in each of the model plants. Equation (9-13), which is derived in Section 9.2.2.3, is used to calculate the average (per megagram) total cost (ATC) of producing steel billets in each plant type under each alternative. The difference in the ATC of producing steel in a given plant under a more stringent emissions control alternative is attributable to the added capital and operating costs of the control equipment. In the extreme case where the entire increase is passed forward in higher steel prices, these changes represent maximum steel price impacts.

The average total cost in 1981 dollars of producing one megagram of steel billets in each model plant under each regulatory alternative is presented in Table 9-29. Uncontrolled carbon steel shops can produce steel billets at a total cost per megagram of between $186.35 and $301.48. This spread of approximately $120 per mg in ATC is an indication of significant economies of scale to be realized in electric arc furnace steel shops. The highest ATC of production is realized in a 22.7-Mg vessel shop with a molten steel capacity of only 37,420 Mg per year. One Mg of carbon steel billets can be produced for $115.13 less in a shop with a 272.2-Mg vessel and an annual capacity of 596,000 Mg of raw steel.

The 1981 producer price for carbon steel billets is $412.16 per Mg. The spread between market price and the ATC of production in these shops varies from $111 to $226. This difference is the reason that these model plants all yield positive net present values.

The 1981 producer price for stainless steel billets is $715.18 per Mg. The specialty steel shops modeled here, if uncontrolled, can produce these billets at a cost of $524.15 to $636.50 per Mg. Again, this spread of $78 to $191 between price and ATC accounts for the profitabilty of these plants, as measured by NPV.

TABLE 9-29. AVERAGE TOTAL COST ASSUMING 6.2 PERCENT WEIGHTED AVERAGE COST OF CAPITAL[a]

(1981 $/Mg)

Model Plant	No Control	Regulatory Alternative		
		1 (Baseline)	2	3
1	301.48	320.62	320.76	321.21
1[b]	301.48	320.62	na	319.98
2	221.77	233.94	234.15	234.31
3	186.35	191.41	191.55	191.92
4	197.60	204.97	205.09	205.27
5	182.40	187.72	187.86	188.25
6	284.42	304.69	304.85	305.31
6[b]	284.42	304.69	na	304.01
7	636.50	672.76	673.58	674.86
8	636.50	667.49	667.71	668.55
9	524.15	546.32	546.68	547.40
10	524.15	544.98	545.20	546.02

[a] Model Plants 1-6 produce carbon billets; plants 7-10 produce alloy billets.

[b] Total Furnace Enclosure Option

NOTE: na = not applicable.

As expected, the ATC of producing steel increases when plants are required to meet the baseline standard. The ATC of producing carbon steel billets under regulatory alternative 1 increases to a range of $191.41 to $320.62 per Mg. The cost per Mg of producing alloy billets is $546.32 to $672.76 at baseline.

Under proposed regulatory alternative 2 or 3, the ATC of production increases only slightly from baseline for most plants and declines for all others. The ATC of carbon steel is between $187.86 and $320.76 under alternative 2, and between $188.25 and $321.21 under alternative 3. The control of model plants 1 and 6 using total furnace enclosures to achieve alternative 3 actually reduces from baseline the ATC of producing carbon steel billets to $319.98 and $304.01, respectively.

The ATC changes associated with moving to more stringent controls are more explicitly presented in Table 9-30. Moving from no control to baseline increases the ATC of production by $5.06 to $20.26 per Mg for carbon shops and $20.83 to $36.27 per Mg for specialty shops. These cost increases represent impacts of 2.7 percent to 7.1 percent for carbon steel and 4.0 percent to 5.7 percent for specialty steel.

Cost impacts measured relative to baseline alternative 1 are generally quite small for the proposed alternatives. The impacts on ATC of alternatives 2 and 3 are all under $1 per Mg for all carbon plants. The impacts are likewise small in percentage terms. The greatest cost impact is the 0.31 percent increase in ATC for model plant 7 under alternative 3.

The average total cost data presented above pertain to estimates using a weighted average cost of capital of 6.2 percent. Analogous estimates using a 10 percent cost of capital are presented in Tables 9-31 and 9-32. The ATC of steel is higher when the cost of capital is higher because the higher cost of borrowed funds must be recovered. The differences, however, are not great.

The average total cost and net present value estimates presented in this and the previous section indicate that the modeled steel shops with electric arc furnaces and, in the case of specialty shops, with argon-oxygen decarburization vessels are profitable investments given the current market price of steel and the cost of capital to steel firms. This holds true for all regulatory alternatives. If the input data and assumptions implicit in the discounted cash flows model are correct, the potential maximum impacts of the proposed regulations on stockholders as measured by

TABLE 9-30. AVERAGE TOTAL COST IMPACTS ASSUMING 6.2 PERCENT WEIGHTED AVERAGE COST OF CAPITAL (1981 $/Mg)

	Regulatory Impact From Baseline[a]					
	Regulatory Alternative					
Model	1		2		3	
Plant	1981$	percent	1981$	percent	1981$	percent
1	19.13	6.35	0.14	0.04	0.59	0.18
1[b]	19.13	6.35	na	na	-0.64	-0.20
2	12.17	5.49	0.22	0.09	0.37	0.16
3	5.06	2.72	0.14	0.07	0.50	0.26
4	7.38	3.73	0.12	0.06	0.30	0.15
5	5.32	2.91	0.15	0.08	0.53	0.28
6	20.26	7.12	0.16	0.05	0.62	0.20
6[b]	20.26	7.12	na	na	-0.68	-0.22
7	36.27	5.70	0.81	0.12	2.09	0.31
8	31.00	4.87	0.22	0.03	1.06	0.16
9	22.17	4.23	0.36	0.07	1.08	0.20
10	20.83	3.97	0.22	0.04	1.04	0.19

[a] Impact of baseline regulatory alternative 1 is measured from no control.

[b] Total Furnace Enclosure Option

NOTE: na = not applicable.

TABLE 9-31. AVERAGE TOTAL COST ASSUMING 10.0 PERCENT WEIGHTED AVERAGE COST OF CAPITAL[a]
(1981 $/Mg)

Model Plant	No Control	Regulatory Alternative		
		1 (Baseline)	2	3
1	321.01	344.97	345.25	345.78
1[b]	321.01	344.97	na	344.28
2	234.55	249.51	249.83	250.05
3	190.83	196.75	196.94	197.37
4	205.57	214.45	214.62	214.84
5	185.38	191.72	191.93	192.40
6	296.97	323.04	323.37	323.91
6[b]	296.97	323.04	na	322.28
7	677.23	723.51	724.49	726.11
8	677.23	716.15	716.53	717.56
9	552.28	580.38	580.85	581.77
10	552.28	578.51	578.81	579.89

[a] Model Plants 1-6 produce carbon billets; plants 7-10 produce alloy billets.

[b] Total Furnace Enclosure Option

NOTE: na = not applicable

TABLE 9-32. AVERAGE TOTAL COST IMPACTS ASSUMING 10.0 PERCENT WEIGHTED AVERAGE COST OF CAPITAL

Model Plant	Regulatory Impact From Baseline[a]					
	Regulatory Alternative					
	1		2		3	
	1981$	percent	1981$	percent	1981$	percent
1	23.96	7.46	0.28	0.08	0.81	0.24
1[b]	23.96	7.46	na	na	-0.69	-0.20
2	14.96	6.38	0.31	0.13	0.54	0.22
3	5.91	3.10	0.19	0.10	0.63	0.32
4	8.89	4.32	0.16	0.08	0.39	0.18
5	6.34	3.42	0.21	0.11	0.68	0.35
6	26.07	8.78	0.33	0.10	0.87	0.27
6[b]	26.07	8.78	na	na	-0.76	-0.24
7	46.28	6.83	0.98	0.14	2.60	0.36
8	38.92	5.75	0.39	0.05	1.42	0.20
9	28.10	5.09	0.47	0.08	1.39	0.24
10	26.23	4.75	0.31	0.05	1.38	0.24

[a] Impact of baseline regulatory alternative 1 is measured from no control.

[b] Total Furnace Enclosure Option

NOTE: na = not applicable.

NPV reductions and the potential maximum price imparts as measured by ATC changes are negligible.

Several qualifications to the above statements are worthy of mention. To begin, the observed differences between market price and average total costs are more substantial than would be expected in a competitive market with free entry (see Section 9.1.3.6). This may be an indication that inaccuracies in the cost data or elsewhere are leading to underestimation of ATC and a resulting overstatement of project profitabilty. In response to this objection, however, it is noteworthy that these are new plants incorporating the best technology to date, and are expected to have low average costs. Not only do they employ the lowest cost steel melting technology, but low cost continuous casters as well. Further, firms are currently building plants of this type at a rapid rate, which is an indication that they themselves perceive rents to be earned.

Another qualification relates to the impact of these proposed regulations alone as distinct from the cumulative impacts of other current and proposed regulatory requirements. Note, for example, that the impacts of regulatory alternative 1 (baseline) relative to no control, are the most substantial. Other regulations governing, for example, water emissions and plant safety, may impose added costs. A prospective builder considers all current and, to the best of his ability, future regulatory requirements in his decision. Still, this analysis concludes that these modeled shops are profitable meeting both current requirements and the proposed New Source Performance Standards.

Finally, the discounted cash flows model employed may fail to adequately account for investment uncertainties. Increases in input costs, for example the cost of scrap, would tend to reduce plant profitability. Steel price reductions would have the same effect. Potential changes in the cost of capital, in corporate income tax rates, in depreciation laws and other factors make the capital budgeting decision more difficult and risky than this analysis indicates.[101]

9.3.3.3 Output, Employment and Imports Impacts. Estimates of NSPS impacts on output and employment in the domestic steel industry and on steel imports are presented in this section. Impacts are presented for the year 1987 for all model plants assuming that the real market price of steel in 1987 increases from its baseline price by an amount exactly equal to the change in ATC resulting from the regulatory alternatives. All impacts are computed using the estimated weighted average cost of capital of 6.2 percent.

9.3.3.3.1 Impacts on steel output. Domestic steel production in 1987 is projected to total 119.7 million Mg. Of this total, 101.7 million Mg will be carbon steel and 18.0 million Mg will be specialty steel. If the real price of domestic steel increases as a result of the NSPS, demand for domestic steel would be expected to decline; industry output would be below the 119.7 million Mg projection.

For each model plant, the projected change in industry output is computed assuming the price of carbon or specialty steel increases by an amount equal to the change in ATC. The percentage change in ATC resulting from each regulatory alternative is multiplied by an estimated own-price elasticity of demand for specialty steel of -1.86.[102] These percentage changes are then multiplied by the baseline carbon or specialty steel projections for 1987 to yield the relevant output reductions. Results of these computations are presented in Table 9-33.

Table 9-33 indicates that 1987 domestic production of carbon semi-finished steel would be 0.08 million Mg lower under regulatory alternative 2 than under baseline if all projected new EAF capacity was met by the construction of plants like model plant 1. This impact represents a reduction of under one-tenth of one percent from the baseline projection of 101.7 million Mg. The production impacts of regulatory alternatives 2 and 3 are in general quite small. Percentage impacts from baseline vary from -0.06 to -0.22 percent for alternative 2 and from -0.58 to 0.41 percent for alternative 3.

9.3.3.3.2 Steel industry employment impacts. Estimated impacts on domestic steel employment are presented in Table 9-34. They are computed by multiplying the estimated output changes in Table 9-33 by an employment-to-output coefficient of 3,663 workers per million megagrams.[28]

While the employment impacts of baseline alternative 1 relative to no control are measured in tens of thousands of jobs, the impacts of the new, proposed standards are much smaller. The impact on employment resulting from moving from baseline to regulatory alternative 2 ranges from a loss of 40 jobs to a loss of 642 jobs, depending on the affected facility. The impacts of alternative 3 range from a gain of 1,538 jobs to a loss of 1,963

TABLE 9-33. DOMESTIC STEEL PRODUCTION IMPACTS FOR 1987[a]

Model Plant	Regulatory Impact From Baseline[b]					
	Regulatory Alternative					
	1		2		3	
	10^6 Mg	percent	10^6 Mg	percent	10^6 Mg	percent
1	-12.01	-11.80	-0.08	-0.08	-0.35	-0.34
1[c]	-12.01	-11.80	na	na	0.38	0.37
2	-10.38	-10.21	-0.18	-0.17	-0.30	-0.30
3	-5.14	-5.05	-0.14	-0.13	-0.50	-0.49
4	-7.06	-6.94	-0.11	-0.11	-0.27	-0.27
5	-5.51	-5.42	-0.15	-0.15	-0.54	-0.53
6	-13.48	-13.25	-0.10	-0.10	-0.38	-0.38
6[c]	-13.48	-13.25	na	na	0.42	0.41
7	-1.91	-10.60	-0.04	-0.22	-0.10	-0.58
8	-1.63	-9.06	-0.01	-0.06	-0.05	-0.29
9	-1.42	-7.87	-0.02	-0.12	-0.07	-0.37
10	-1.33	-7.39	-0.01	-0.07	-0.06	-0.35

[a] Assuming 6.2 percent weighted average cost of capital.

[b] Impact of baseline regulatory alternative 1 is measured from no control.

[c] Total Furnace Enclosure Option

NOTE: na = not applicable.

TABLE 9-34. DOMESTIC STEEL INDUSTRY EMPLOYMENT IMPACTS FOR 1987[a]

Model Plant	Impact From Baseline[b] of Regulatory Alternative					
	1		2		3	
	jobs	percent	jobs	percent	jobs	percent
1	-43,976	-11.80	-308	-0.08	-1,275	-0.34
1[c]	-43,976	-11.80	na	na	1,392	0.38
2	-38,020	10.21	-642	-0.17	-1,102	-0.30
3	-18,817	-5.05	-496	-0.13	-1,820	-0.49
4	-25,872	-6.94	-394	-0.11	-1,005	-0.27
5	-20,195	-5.42	-542	-0.15	-1,963	-0.53
6	-49,368	-13.25	-362	-0.10	-1,409	-0.38
6[c]	-49,368	-13.25	na	na	1,538	0.41
7	-6,987	-10.60	-148	-0.22	-382	-0.58
8	-5,972	-9.06	-40	-0.06	-194	-0.29
9	-5,186	-7.87	-81	-0.12	-241	-0.37
10	-4,873	-7.39	-48	-0.07	-233	-0.35

[a] Assuming 6.2 Percent Weighted Average Cost of Capital

[b] Impact of baseline alternative 1 measured from no control

[c] Total Furnace Enclosure Option

NOTE: na = not applicable.

jobs. Even the greatest impact, that for model plant 5 under alternative 3, represents a loss from baseline employment of only 0.53 percent.

It is important to remember that these employment losses are not layoffs. Rather, they are jobs that will not be created by 1987 that otherwise would have been. Also, these computed losses do not take account of any employment increases that might result in other sectors of the economy. For example, because aluminum competes with steel, employment increases might be expected in the aluminum industry. Employment gains are expected to occur in industries that produce control equipment.

9.3.3.3.3 Impacts on steel imports. As the real price of domestic steel rises relative to that for imported steel, domestic users are expected to increase their purchases of foreign steel. It has been estimated that a 1 percent increase in the domestic price for finished steel results in a 1.51 percent increase in steel imports.[103] This import elasticity is multiplied by the percentage change in ATC from Table 9-30 to compute the percentage change expected to result in steel imports from the NSPS on EAF secondary emissions.

If the same quantity of steel imported into the U.S. in proportion to domestic production is imported in 1987 as in 1979, steel imports will total 20.3 million Mg in 1987. Of this total, 19.3 million Mg will be carbon steel and 1.0 million Mg will be specialty steel.[104] The NSPS induced percentage change in steel imports estimated as explained above is multiplied by the relevant baseline import projection to compute import impacts. Estimates are presented in Table 9-35.

In general, more stringent regulatory alternatives result in greater steel imports. The greatest impact on carbon steel imports relative to baseline is the 0.08 million Mg increase resulting from imposing regulatory alternative 3 on model plant 5. This represents, however, only a 0.43 percent increase. The impacts on specialty steel imports are all under 0.01 Mg.

9.3.4 Anticipated Economic Impacts

Section 9.2.3 presented ranges of impacts on NPV assuming full cost absorption, and on price and other variables assuming full cost pricing. The purpose of this section is to present estimates of impacts on net

TABLE 9-35. STEEL IMPORTS IMPACTS FOR 1987[a]

Model Plant	Regulatory Impact From Baseline[b]					
	Regulatory Alternative					
	1		2		3	
	10^6 Mg	percent	10^6 Mg	percent	10^6 Mg	percent
1	1.85	9.58	0.01	0.07	0.05	0.28
1[c]	1.85	9.58	na	na	-0.06	-0.30
2	1.60	8.29	0.03	0.14	0.05	0.24
3	0.79	4.10	0.02	0.11	0.08	0.40
4	1.09	5.64	0.02	0.09	0.04	0.23
5	0.85	4.40	0.02	0.12	0.08	0.43
6	2.08	10.76	0.02	0.08	0.06	0.31
6[c]	2.08	10.76	na	na	-0.06	-0.33
7	0.09	8.60	d	0.18	d	0.47
8	0.07	7.35	d	0.05	d	0.24
9	0.06	6.39	d	0.10	d	0.30
10	0.06	6.00	d	0.06	d	0.29

[a] Assuming 6.2 percent weighted average cost of capital.

[b] Impact of baseline regulatory alternative 1 is measured from no control.

[c] Total Furnace Enclosure Option

[d] Less than 0.005 million Mg.

NOTE: na = not applicable.

present value, steel price, and other relevant variables that are considered most likely to result under the proposed alternatives. The impacts that actually occur depend on a number of factors including the types of plants actually built and the extent to which cost increases are passed forward. The first factor is addressed in Section 9.2.4.1 while Section 9.2.4.2 deals with the cost-price mechanism.

9.3.4.1 Model Plant Selection. Ten model plants are described in Chapter 6. The plants vary in certain respects but are all electric arc process steel furnace projects. As seen in Table 9-23, each model plant has associated with it a unique set of fixed capital and annual operating costs. Accordingly, as evidenced in Tables 9-25 and 9-29, each project has associated with it a unique net present value and average total cost. It is thus clear that the economic impacts that will actually result from the proposed NSPS will depend in part on which types of facilities are actually constructed.

Of the model plants investigated in this report, plant 4 is believed to best typify new EAF carbon steel shops to come on line over the next several years. This represents a 136.1 Mg ultra high power vessel shop. Model plant 7 is thought to be most representative of specialty steel shops to be built in the near future.

These models are considered representative of future projects partly because they are similar in capacity to recently constructed shops. The separate control of emissions from the EAF and EAF/AOD vessels in model plant 7 allows greater operational flexibility than the common control of model plant 8.

9.3.4.2 Estimates of Anticipated Impacts. The economic impacts that are expected to result from the proposed regulatory alternatives are estimated assuming that model plants 4 and 7 typify future EAF construction through 1987. Table 9-36 has been constructed from Tables 9-25 and 9-29.

The ATC data in Table 9-36 are a certain result of the NSPS given that the cost data and model parameter values are correct. That is, the total cost of producing a megagram of steel in each model plant is sure to increase as a result of the NSPS. The impact of this change on other relevant variables is less certain. Two extreme results are possible. If the market prices of carbon and specialty steel were to remain unchanged,

TABLE 9-36. NET PRESENT VALUE AND AVERAGE TOTAL COST DATA FOR MODEL PLANTS 4 AND 7[a]

	Regulatory Alternative					
	1		2		3	
Model Plant	NPV (10^6 1981 $)	ATC (1981 $/Mg)	NPV (10^6 1981 $)	ATC (1981 $/Mg)	NPV (10^6 1981 $)	ATC (1981 $/Mg)
4	359.463	204.97	359.261	205.09	358.947	205.27
7	6.332	672.76	6.211	673.58	6.020	674.86

[a] Assuming 6.2 percent weighted average cost of capital.

the proposed regulations would diminish the difference between price and ATC, thus reducing the NPV's of these plants. The NPV of carbon shop model plant 4 would decline from its baseline \$359.463 million to \$359.261 million under alternative 2, or to \$358.497 million under alternative 3. These 0.06 and 0.27 percent NPV reductions would be felt as a one-time reduction in wealth spread across all holders of outstanding shares of stock of affected firms. As seen in Table 9-36, similar NPV reductions would result from the proposed regulations on specialty shop model plant 7 assuming full cost absorption.

In a case of full cost pricing, project NPV's would remain unchanged from their baseline values as market price rose by the same amount as ATC. A most relevant question thus becomes: what is the mechanism linking ATC to price and what will be the result of this mechanism in this circumstance?

9.3.4.2.1 Analytical Framework

The analytic framework that is applied in this analysis depends heavily upon the work of W. E. G. Salter.[105] The framework is soundly based on standard microeconomic theory, employs a comparative statistics approach, and assumes certainty in relevant markets. Price and quantity are determined by market forces, not by individual market participants.

This approach recognizes that there are two distinctly different types of production decisions: operating decisions and investment decisions.

Operating decisions involve simply whether or not a firm with plant and equipment already in place purchases inputs to produce output. These are sometimes called short-run decisions since the decision period is sufficiently short that certain inputs, namely plant and equipment, are fixed. A profit-maximizing firm will operate existing capital as long as the market price for its output exceeds it unit variable costs of production. As long as market price even marginally exceeds average variable (operating) cost, the producing plant will cover not only the cost of its variable inputs but will cover part of its capital cost as well. A profit-maximizing firm will not pass-up an opportunity to recover even part of the initial investment it made in the plant and durable equipment.

Investment decisions differ from operating decisions in that they involve whether or not the firm should put in place new plant and/or equipment.

The investment decision is sometimes called a long-run decision since the time frame is sufficiently long that all inputs, including capital, are variable. A firm will not invest in new capital unless current and expected future market price is sufficient to cover both the cost of operating the new capital (variable costs) and the cost of purchasing and owning the capital, including a normal rate of return. Put differently, a firm will not invest unless market price equals or exceeds average total cost.

The hypothesized supply schedule from a single existing plant is depicted in panel (a) of Figure 9-1. Given the capital in place, the plant owner is willing to supply output Q* as long as market price equals or exceeds the plant's average operating cost (AOC). If market price is below AOC, the owner is unwilling to produce even a fraction of Q* because a per unit loss would be incurred. If market price should substantially exceed AOC, the owner would be willing to produce output beyond Q* but is unable to do so given plant capacity.

The hypothesized supply schedule from an as yet unconstructed plant is depicted in panel (b) of Figure 9-1. Because the plant and equipment are not yet in place, all inputs are variable. The scale (capacity) of the plant itself is variable. Thus, the supply schedule does not turn up at any output rate. The assumption of a perfectly elastic plant supply curve is probably realistic. It is unlikely that input factor prices would be bid-up by the demands of a single plant.

Supply will not be forthcoming from the new plant, that is, it will not be built, unless market price exceeds the average total cost of production. The plant will be constructed only if the anticipated market price is sufficiently above average operating cost to recover the capital investment and provide a normal return on the capital.

With an understanding of plant-level supply, focus is now directed towards market-level considerations. In panel (a) of Figure 9-2, the conventional equilibrium determination of market price and quantity is depicted. Market demand (D) is assumed to be downward sloping. Because an NSPS affects new supply facilities, it is the supply schedule (S) that is of interest here.

During any period of time, the market output of a good is the sum of the quantities produced by individual plants. As discussed above, once a

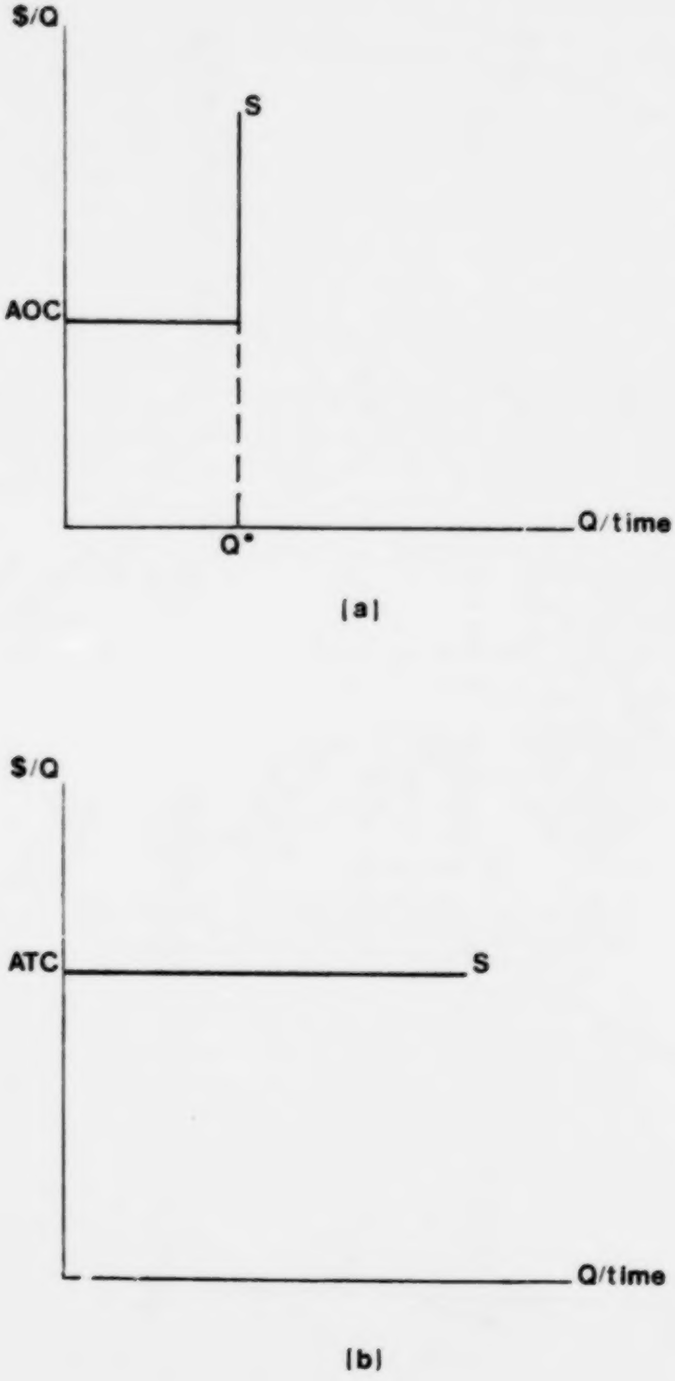
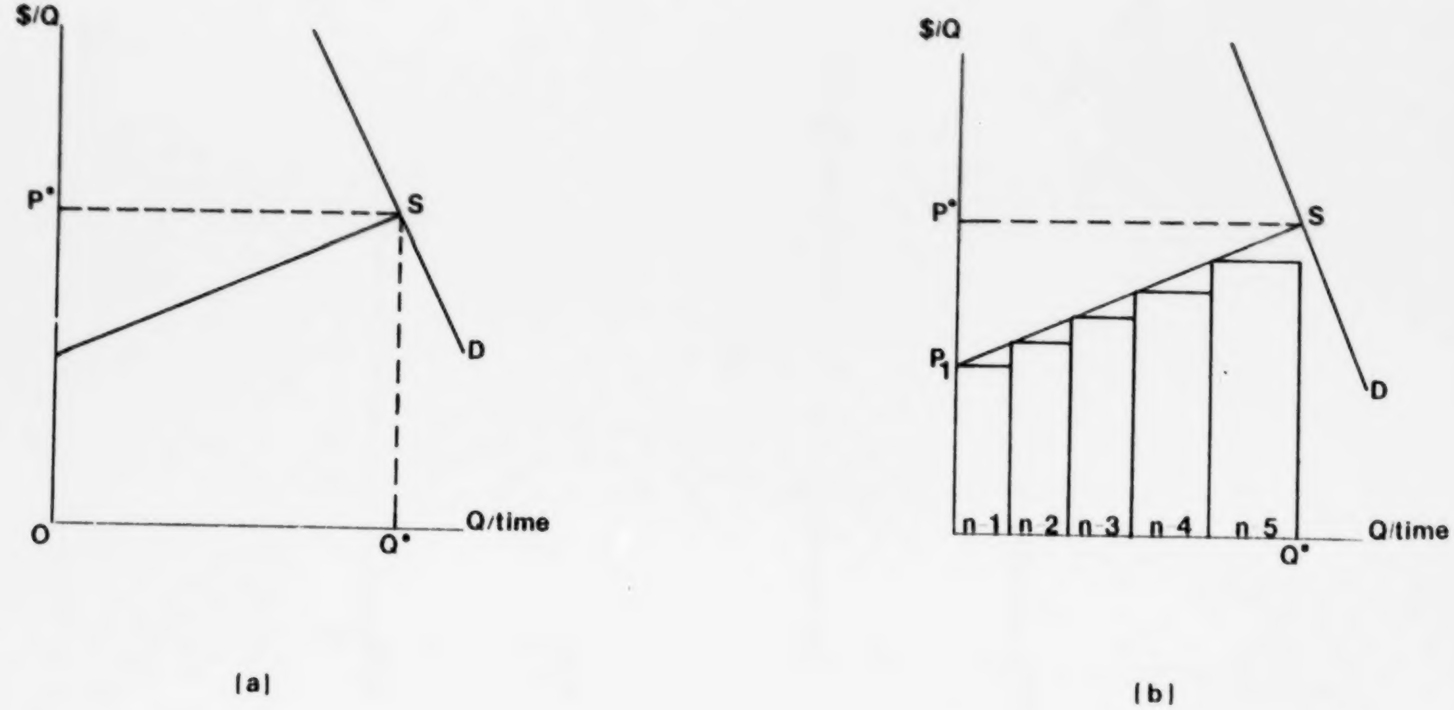


Figure 9-1. Supply schedules for constructed and unconstructed plants.


$/Q
P*
S
D
O
Q*
Q/time
(a)
$/Q
P*
S
P1
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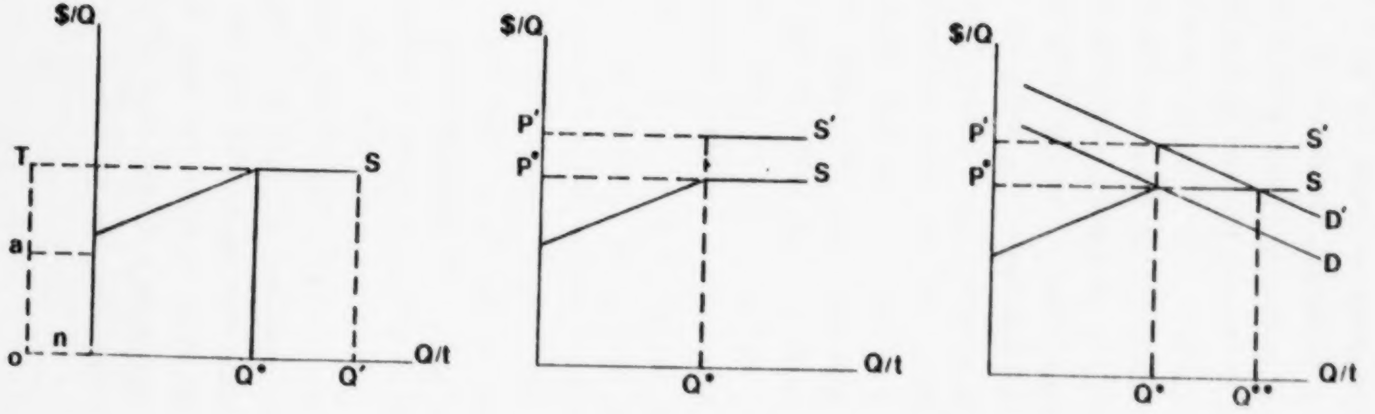
n 1
n 2
n 3
n 4
n 5
Q*
Q/time
(b)

Figure 9-2. NSPS effects on market price and quantity.



(c) (d) (e)

Figure 9-2. Continued

plant is in place, it will produce as long as market price is equal to or greater than its average operating cost. Failure to do so would involve passing-up an opportunity to earn some return on existing fixed capital. In general, newer plants will have capital of superior technology to that of older plants. Thus, the average operating costs of newer plants will generally be lower than those of older plants. Thus, each plant is willing to produce output at a different market price.

The willingness of existing plants with different average operating costs to produce at a different minimum market price results in the upward slope of the supply schedule. This is illustrated in panel (b). The newest plant, which is of vintage n-1, has the lowest average operating cost. Thus, it is willing to supply output as long as price at least equals P_1. Plants constructed in successively earlier periods have increasingly higher average operating costs and are willing to produce only at higher prices. The oldest plant, produced in period n-5, has the highest average operating cost and is the oldest existing plant that is willing to produce at prevailing price P*; it is thus said to be a marginal plant.

Now that it is understood why the supply schedule is upward sloping to Q*, it is time to investigate the slope of the supply schedule beyond Q*. This is a question of long-run supply, since output in excess of Q* can be produced only after a new plant has been constructed. The question becomes then, what is the market price at which a new plant will be constructed?

Recall from the discussion of panel (b) in Figure 9-1 that all costs of an unconstructed plant are variable costs. The prospective builder will invest in the new plant only if the anticipated market price is sufficiently high to cover average total cost, which is average operating cost plus average capital cost, including a normal return on the capital.

In panel (c) of Figure 9-2, plant n represents the as yet unconstructed plant. Because it will incorporate the latest technology, it will have low operating costs. In the figure, oa is the average operating cost of the new plant. The cost component aT is the average capital cost of the new plant. This cost component represents the return per unit output in excess of operating cost required in order to repay the principal of the original capital investment and earn a normal rate of return on that investment. The firm's desire to recover the investment principal and earn a normal return holds for both existing facilities and facilities under consideration. In the latter case though, even these costs are variable, indeed they are avoidable. The firm has the alternative of not building at all; i.e., of investing in another project. Thus, the new plant will be built only if market price equals or exceeds average total cost oT. Once built, it will supply output Q' - Q* as long as market price covers average operating cost; its capital costs become sunk. Thus, the long-run supply schedule, at least from Q* to Q', is elastic at price = average total cost of the best technology plant.

The validity of assuming perfectly elastic long-run market supply is unknown. For relatively small increases in market output resulting from the construction of, say, only a few new plants, the assumption is probably reasonable. If, however, the number of newly constructed plants increased market demand for factors of production significantly, it is possible that factor prices would be bid-up and that long-run supply would be upward-sloping. Significantly additional quantities of iron and steel scrap, for example, might be forthcoming at higher market prices. The implications for impact estimates of assuming perfectly elastic long-run market supply will be addressed later.

With an understanding of the decision criterion for new plant construction, it is possible to analyze the effects of an NSPS in a market initially in both short-run and long-run equilibrium. In panel (d), the long-run supply schedule (S) beyond Q* is determined by the average total cost of the design-stage plant. Prior to the NSPS, some unknown number of new plants would have been constructed during time period n + 1. These new plants would have been constructed until the expansion of market output relative to demand drove market price below P*; i.e., until the next plant to come on line would be unable to cover average total cost. In general, an NSPS raises both the costs of building and operating a new plant. The result is an increase in the average total cost of production. In panel (d), the increase in average total cost results in an upward shift of the supply schedule beyond Q*, from S to S'. The anticipated market price required to bring the new plant on line is now P'. Only at this higher price can the investor cover operating costs and earn a normal rate of return.

In a competitive output market, the prospective investor is a price-taker;

his individual decisions do not affect market price. If market price is P* (panel (d)) he cannot simply sell his own output at price P'. Unless market-wide forces cause price to increase from P* to P', investment in the plant will fail to yield a normal rate of return. Funds will instead be invested in an investment that does yield a normal rate. New plant investment will be delayed until market forces bring about market price P'. The number of new plants constructed in period n + 1 will be lower with the NSPS than without.

A likely circumstance is that increasing demand for the product, as a result of economic growth, relative to the supply from existing plants will drive up product price. This is illustrated in panel (e). When demand shifts from D to D', market price P' will prevail, allowing a normal rate of return on a new, controlled plant.

Two consequences of an NSPS have already become apparent from the model. The NSPS, by increasing the average total cost of production in the new plant, raises the market price at which it is "profitable" to build that plant. The result is a delay in construction until market forces, such as an increase in demand, bring about an increase in market price. There is thus a price impact and a new plant construction impact.

Panel (e) indicates there is a third impact - the impact on total quantity traded. In the absence of the NSPS, a shift in demand from D to D' would have resulted in market trade of Q** units per period of time. In the presence of the NSPS, only Q* units are traded given D'. There is an output impact of Q** - Q* units.

The steel market may well be in short-run equilibrium. The market is clearing with neither excess supply nor excess demand.

The net present value and average total cost results presented in Section 9.2.4.2 indicate that the domestic steel market is not, however, presently in long-run equilibrium: the average total costs of model plants 2 and 7 at baseline are considerably below the market prices of $412.16 per Mg of carbon steel and $715.18 per Mg of specialty steel. Thus, it is profitable for firms to build EAF plants of this type; i.e., the plant NPV's are positive. This is in keeping with our observation that electric arc furnace steel shop construction is brisk and our projection of continued growth in EAF capacity.

In order to determine the economic impacts of a NSPS on these new plants, consider first the expected market adjustments in the absence of new standards. Panel (a) of Figure 9-3 depicts the market for (carbon) steel in disequilibrium. Output Q is being traded at market price P determined by the intersection of demand and supply (S) from existing firms. However, the ATC of production for the newest, unconstructed plant (model plant 2) is below market price P. Long-run equilibrium will be restored only when market price falls to P_e = ATC. Given demand, and for simplicity given supply from existing plants, the construction of some number of new plants will expand supply relative to demand until market price falls to P_e. Once market price P_e is acheived there will be no further incentive to build new plants.

The impact of either of the two proposed regulatory alternatives on model plant 4 can now be analyzed. The standard increases the ATC of production for model plant 4 from ATC to ATC'; e.g., from $203.12 to $203.35 for alternative 3, an increase of $0.23 per Mg. In panel (b) of Figure 9-3, the ATC of the regulated new plant, ATC', is higher than the ATC of the unregulated new plant, ATC in panel (a). The ATC of production for the regulated new plant is still below current market price P, $412.16 per Mg. In the presence of the standard, construction of new plants will continue until the long-run equilibrium price is achieved; i.e., until the NPV of a new plant is zero. The new long-run equilibrium price is no longer P_e however, but P'_e. Thus, fewer plants will be constructed before supply will be expanded to Q'_e, restoring long-run equilibrium.

The anticipated economic impacts of the proposed standards can thus be summarized. There is a price and quantity impact associated with a standard on new electric arc furnace steel facilities. However, the price impact would be felt not as an increase in the price of steel above the current price but rather as an increase above the (lower) market price that would have obtained in the absence of the standard: the difference between P_e and P'_e. Likewise, the output impact would not be felt as a reduction from current output but rather as a reduction from the projected baseline output: the amount Q_e - Q'_e. There is no net present value impact because the new long-run equilibrium steel price is just sufficiently higher than the baseline long-run equilibrium price to compensate producers for increased production

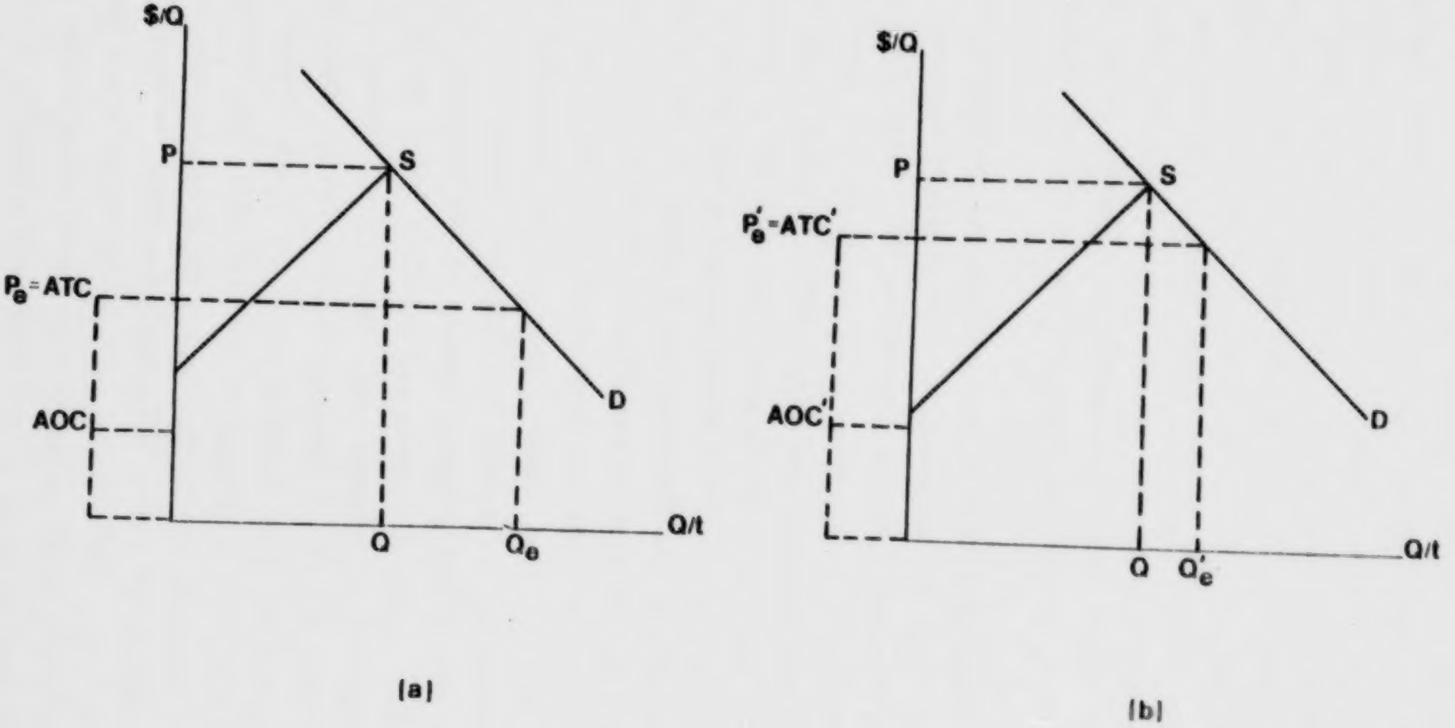


Figure 9-3. NSPS effects on the average total cost of new plants, equilibrium price and equilibrium quantity.

costs. The higher price for domestic steel will lead to an increase in steel imports and the reduction in domestic output will have an impact on industry employment.

The impact estimates presented below assume perfectly elastic long-run market supply. If long-run supply is upward sloping, different impacts will result. An effort is made here to discuss the qualitative implications of upward-sloping long-run supply on the impact estimates.

In the case of perfectly elastic long-run market supply, long-run equilibrium price is equal to today's average total cost of the best technology plant. However, if factor prices are bid-up as more and more of these plants begin producing, average total cost will increase with market output and the long-run equilibrium price will be determined by the plant supplying the marginal output. Thus, long-run equilibrium price would be expected to be higher with upward-sloping long-run market supply. Logically, with downward-sloping demand, market clearing output would be lower at the higher long-run equilibrium price.

The absolute impacts on both price and quantity are lower in the case of upward-sloping supply. That is, the differences between controlled and uncontrolled long-run equilibrium price and quantity are lower when supply slopes upward. Because consumers purchase less at higher prices, market clearing quantity falls and fewer new plants come on line. With fewer plants producing, input prices are not bid-up as severely. Hence, there is a smaller increase in price for the vertical supply shift the more upward sloping is supply.

To summarize, long-run equilibrium price would increase and long-run equilibrium output would decline as long-run supply becomes less elastic. The differences between controlled and uncontrolled prices and quantities would be smaller with less elastic supply.

Again, the estimate impacts presented below assume perfectly elastic long-run market supply. Hence, the impact estimates a biased upward.

9.3.4.2.2 Impact Estimates

Table 9-37 summarizes the anticipated impacts of regulatory alternative 2 on electric arc carbon and specialty steelmaking. The impacts computed are those expected in 1987. Impacts are measured relative to regulatory alternative 1, which is baseline.

TABLE 9-37. SUMMARY OF ECONOMIC IMPACTS FROM BASELINE OF REGULATORY ALTERNATIVE 2[a]

	Carbon Steel (Model Plant 4)	Alloy Steel (Model Plant 7)
Net Present Value	0	0
Steel Price ($/Mg)	0.12 (0.06%)	0.81 (0.12%)
Domestic Output (Mg)	-110,000 (-0.11%)	-40,000 (-0.22%)
Employment (jobs)	-394 (-0.11%)	-148 (-0.22%)
Imports (Mg)	17,000 (0.09%)	b (0.18%)
Total Cost of Regulatory Alternative (10^6 $)[c]	0.608	0.773

[a] Model Parameters:

Cost of capital = 6.2%

Own-price demand elasticity = -1.86

Import elasticity = 1.51

1987 Baseline price = $229.62/Mg - carbon
$652.70/Mg - specialty

1987 Baseline output = 101.7 x 10^6 Mg - carbon
18.0 x 10^6 Mg - specialty

1987 Baseline employment = 372,527 - carbon
65,934 - specialty

1987 Baseline imports = 19.3 x 10^6 Mg - carbon
1.0 x 10^6 Mg - specialty

[b] Less than 5,000 Mg.

[c] See Section 9.2.6, Table 9-41.

There is no anticipated impact on project net present values. The proposed standard would have an estimated price impact of $0.12 per Mg for carbon steel and $0.81 per Mg for specialty steel. These represent price impacts of 0.06 percent and 0.01 percent, respectively. The price increases would lead consumers to purchase 110,000 fewer Mg of carbon steel and 40,000 fewer Mg of specialty steel in 1987. These are reductions of 0.11 and 0.22 percent from 1987 baseline production. These output reductions would lead to fewer employment opportunities in 1987 totaling approximately 542 jobs--an employment loss of about one-tenth of one percent. The price increase of domestic steel would also cause domestic users to substitute foreign for domestic steel. An estimated 17,000 Mg more of carbon steel would be imported under alternative 2 than at baseline.

Table 9-38 summarizes the anticipated impacts of regulatory alternative 3 on electric arc carbon and specialty steelmaking. The impacts computed are those expected in 1987. Impacts are measured relative to regulatory alternative 1, which is baseline.

The anticipated impact on project net present values is zero. It is expected that this alternative would have a $0.30 per Mg impact on the price of carbon steel and a $2.09 per Mg impact on the price of specialty steel. Thus, the price of carbon steel in 1987 would be 0.27 percent higher than it would be in the absence of this regulation and the price of specialty steel 0.58 percent higher. The price increases would lead c onsumers to purchase less domestic steel--270,000 Mg less carbon steel and 100,000 Mg less specialty steel. These output effects of 0.27 percent and 0.58 percent, respectively, would cause proportionate reductions in employment opportunities--an estimated 1,387 fewer jobs in the industry in 1987. The higher prices of domestic steel would also encourage higher imports. An estimated 40,000 Mg more of carbon steel would be imported under regulatory alternative 3 than at baseline.

9.3.5 Capital Availability

This section investigates how the proposed regulatory alternatives will affect the steel industry's ability to raise capital.

TABLE 9-38. SUMMARY OF ECONOMIC IMPACTS FROM BASELINE OF REGULATORY ALTERNATIVE 3[a]

	Carbon Steel (Model Plant 4)	Alloy Steel (Model Plant 7)
Net Present Value	0	0
Steel Price (\$/Mg)	0.30 (0.15%)	2.09 (0.31%)
Domestic Output (Mg)	-270,000 (-0.27%)	-100,000 (-0.58%)
Employment (jobs)	-1,005 (-0.27%)	-382 (-0.58%)
Imports (Mg)	40,000 (0.23%)	b (0.47%)
Total Cost of Regulatory Alternative (10^6 \$)[c]	1.415	1.160

[a] Model Parameters:
Cost of capital = 6.2%
Own-price demand elasticity = -1.86
Import elasticity = 1.51
1987 Baseline price = \$229.62/Mg - carbon
\$652.70/Mg - specialty
1987 Baseline output = 101.7 x 10^6 Mg - carbon
18.0 x 10^6 Mg - specialty
1987 Baseline employment = 372,527 - carbon
65,934 - specialty
1987 Baseline imports = 19.3 x 10^6 Mg - carbon
1.0 x 10^6 Mg - specialty

[b] Less than 5,000 Mg.

[c] See Section 9.2.6, Table 9-42.

To begin, the capital required to build each model plant under each regulatory alternative is compared. Table 9-39 shows capital requirements by plant type uncontrolled, under baseline, and under the two proposed alternatives. The percentage changes in the capital requirement from baseline to alternatives 2 and 3 are also shown.

Note first that the additional capital required to meet alternative 1, which is baseline, over no control is substantial in percentage terms--from a low of 18.95 percent for model plant 4 to a high of 46.22 percent for model plant 6. These same increases are not, however, especially high in dollar terms. The greatest increase is the $9.3 million increase for model plant 9.

The additional capital required over baseline to meet alternative 2 or 3 is relatively small. Regulatory alternative 2 requires an added capital expenditure that never exceeds 1.6 percent of the baseline expenditure. In dollar terms, the greatest increase is $0.36 million (model plant 5). Regulatory alternative 3 also requires little increase in capital expenditures. The greatest increase from baseline is $0.84 million (model plant 5). In percentage terms, alternative 3 has the greatest impact on model plant 5--3.68 percent.

Particular attention should be drawn to the incremental capital requirements for model plants 4 and 7 since these projects are utilized for the anticipated impacts analysis. 190,000 dollars more capital is required to build model plant 4 under alternative 2 and $380,000 more is required under alternative 3. These represent increases from baseline of 0.48 and 0.96 percent, respectively. Construction of model plant 7 requires $60,000 more capital under alternative 2 and $180,000 million more under alternative 3.

One qualification should be discussed. The NSPS on electric steelmaking is only one of several environmental regulations affecting the steel industry. Others include regulations on coking facilities and other steelmaking processes. Each is expected to impose additional capital costs on the industry. Taken together these regulations may result in some difficulties in obtaining financing for some companies. Even this is not certain. Table 9-40 presents the "funded debts to net working capital"

TABLE 9-39. CAPITAL REQUIREMENTS OF REGULATORY ALTERNATIVES

Model Plant	No Control	Capital requirements (10^6 1981 $) Regulatory Alternative 1	2	3	Change from baseline[a] (percent) Regulatory Alternative 1	2	3
1	7.00	8.73	8.78	8.81	24.71	0.57	0.92
1[b]	7.00	8.71	na	8.71	24.43	na	0
2	20.00	24.37	24.52	24.62	21.85	0.62	1.03
3	25.60	30.47	30.77	31.17	19.02	0.98	2.30
4	33.20	39.49	39.68	39.87	18.95	0.48	0.96
5	17.00	22.84	23.20	23.68	34.35	1.58	3.68
6	4.50	6.58	6.64	6.67	46.22	0.91	1.37
6[b]	4.50	6.56	na	6.55	45.78	na	-0.15
7	14.60	18.19	18.25	18.37	24.59	0.33	0.99
8	14.60	17.44	17.50	17.57	19.45	0.34	0.75
9	44.00	53.28	53.45	53.78	21.09	0.32	0.94
10	44.00	52.45	52.59	52.99	19.20	0.27	1.03

[a] Impact of regulatory alternative 1 measured from no control.

[b] Total Furnace Enclosure Option

NOTE: na = not applicable.

TABLE 9-40. INDUSTRY DEBT RATIOS[76]

Industry	Debt ratio[a]
Blast furnaces and steel mills--SIC 3312	87.2
Primary nonferrous metals, NEC--SIC 3339	48.4
Aluminum foundries--SIC 3361	60.6
Primary metal products, NEC--SIC 3399	39.5
Motor vehicles--SIC 3711	41.8
Petroleum refining--SIC 2911	61.2

[a] Debt ratio = $\frac{\text{Funded debts}}{\text{Net working capital}}$

ratio (debt ratio) for several industries. The numerator of this ratio, funded debts, is all obligations with maturities exceeding 1 year, including bonds, mortgages, and term loans. These are the instruments that would likely be utilized to finance a new steel project. The denominator, net working capital, represents the excess of current assets over current liabilities; it represents available liquid funds. The higher the debt ratio, the more difficult it becomes to obtain further capital through debt issue. A ratio in excess of 100 is ordinarily considered excessive.[106]

The debt ratio for the steel industry, 87.2, is a little under the recommended maximum. It is, however, significantly higher than the ratios for other listed industries. This may be some indication that the steel industry has borrowed to its financially practical limit. If this is true, the imposition of regulatory alternatives that require further capital investment could be financially damaging to the industry.

9.3.6 Total Cost of Regulatory Alternatives

The purpose of this section is to compute the total cost of each regulatory alternative. A partial equilibrium analysis is employed to examine all costs measurable in the market for steel. The cost estimates are to be interpreted as gross total costs, not net total costs; i.e., they are costs before the deduction of the monetary value of any environmental benefits resulting from the regulation.

A simple competitive model of the current domestic steel market is depicted in figure 9-4. The supply curve (S_x) from existing firms is upward sloping for the reasons discussed in section 9.2.4.2. Current market price (P) and output (Q) prevail given demand (D). The market is in long-run disequilibrium because the average total cost of production for new, electric arc furnace plants (ATC_N) is below the prevailing market price P. The long-run steel supply schedule is thus elastic (represented by the horizontal segment S_N) and below the prevailing market price for steel.

Owners of newly-constructed electric steel mills stand to earn economic rents as long as the market price for steel exceeds the ATC of the new plant. The long run equilibrium price (P_e), the price at which investors no longer have an incentive to enter the market, is thus equal to ATC_N assuming no changes in technology, factor prices, or demand.

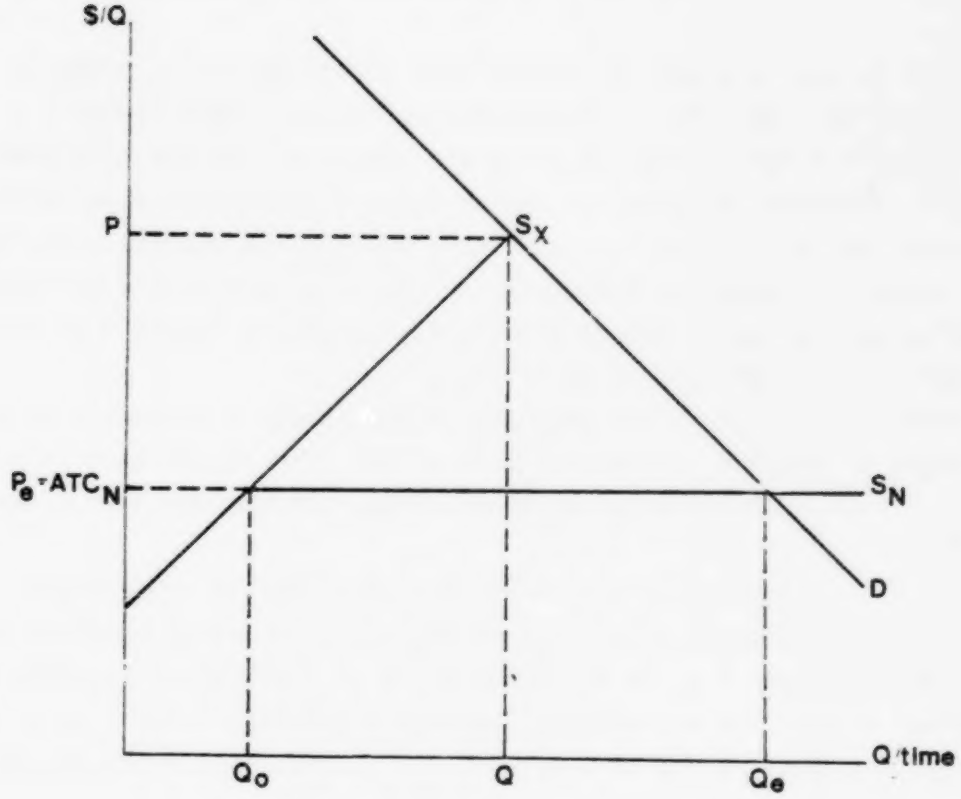


Figure 9-4. Current steel market disequilibrium and long-run equilibrium.

Long-run market disequilibrium is not expected to maintain indefinitely. In time, any frictional delays or market barriers to entry should diminish, allowing new plants to come on line. As they do so, market supply will increase relative to demand, driving market price towards long-run equilibrium price P_e.

There is little reason to believe that the United States domestic steel market will long be in long-run disequilibrium. Many of the conventionally cited barriers to entry are absent for new electric steel mills.[107] Economies of scale are not apparent; electric arc steel mills, which have low unit production costs, have low start-up capital costs as well. Steel is a homogeneous product, so new firms have little difficulty marketing their product. Electric arc mills require no inputs from sources held captive by established firms.

Finally, construction of new electric arc plants is currently quite active and is expected to continue to be brisk. This is evidence both that there is economic incentive to enter the market and that barriers to entry are not prohibitive.

The effects of a new source performance standard are illustrated in figure 9-5. The average total cost of production for a new, electric steel plant increases from ATC_N to ATC_N' as a result of the increased capital and operating costs of the regulation. However, the market is still in a state of long-run disequilibrium as long as $ATC_N' < P$. Post-regulatory market long-run equilibrium now attains at P_e' and Q_e'.

Prior to the standard, total consumers' surplus is equal to the value of the area $P_e bc$--the area below the demand curve and above long-run equilibrium market price P_e. After the standard, consumers' surplus is defined by the area $P_e' bd$. Thus, the readily apparent effect of the standard is to reduce consumers' surplus by the amount $P_e bc - P_e' bd = P_e P_e' dc$. Consumers now pay more per unit of output $(P_e' - P_e)$ and consume less $(Q_e - Q_e')$.

We are now in a position to calculate the total cost of the regulation, but care must be taken to avoid double-counting and including transfers as a cost. The intuitively most apparent cost of the regulation is the real resource cost associated with the expenditures by investors in new plants to meet the standard. New plants that come on line in the presence of the standard incur higher capital and operating costs than

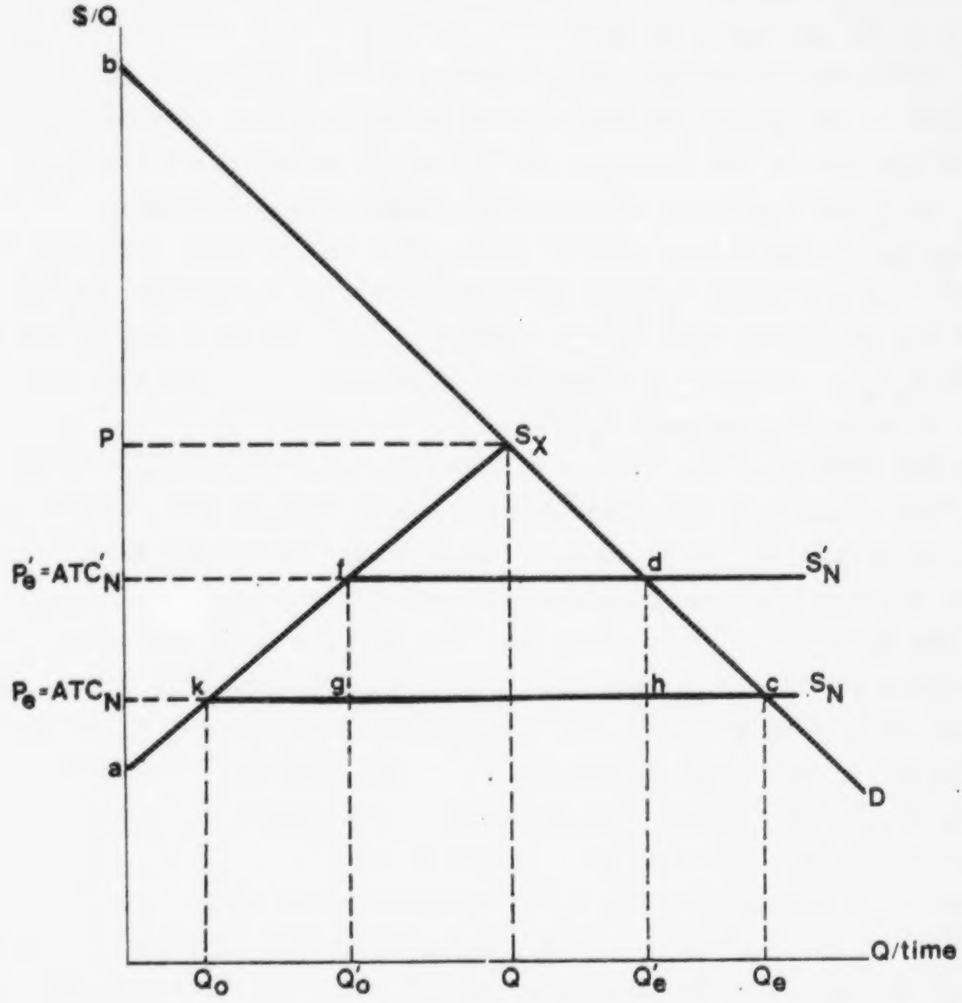


Figure 9-5. NSPS effects on U.S. steel market long-run equilibrium

would prevail in the absence of the standard. This real resource cost is paid by consumers (loss of consumers' surplus) and is equivalent to the rectangular area gfdh. Consumers pay a higher price per unit of output equal to $P'_e - P_e$ for each of the $Q'_e - Q'_o$ units produced by new firms. This component of the cost of the regulation will hereafter be referred to as the "new plant real resource cost".

A second readily recognizable component of the total cost of the regulation is the deadweight loss in consumers' surplus. Consumers' surplus equal to the area of the triangle hdc is lost as market price increases from P_e to P'_e and consumers reduce their consumption accordingly.

Thus far a significant portion (area gfdc) of the total reduction in consumers' surplus (area $P_eP'_e$dc) has been identified as part of the total cost of the New Source Performance Standard. Still to be accounted for is the area $P_eP'_e$fg. As seen in figure 9-5, this area is divided into two parts: triangle kfg and area $P_eP'_e$fk.

In the absence of the NSPS, old (preexisting) plants produce output Q_o. In the presence of the standard, old plants produce more output--Q'_o. This is so because in the presence of the standard the higher market price makes it profitable for more old plants to continue production. Output equivalent to $Q'_o - Q_o$ is produced by new, low cost plants in the absence of the standard but by old, higher cost plants with the standard. Thus, real resources of a value equal to area kfg are used to produce $Q'_o - Q_o$ units of output with the NSPS that are saved without the standard. The value of triangle kfg is thus a real resource cost of the regulation, and will be referred to as the "old plant real resource cost."

The final component of the total reduction in consumers' surplus to be accounted for is area $P_eP'_e$fk. This component, it will be shown, is not a cost of the regulation for some undetermined length of run but becomes a real resource cost of the regulation in the very long run.

In the long-run market depicted in figure 9-5, area $P_eP'_e$fk represents a transfer from consumers' to producers' surplus. Without the standard, owners of old plants enjoy rents equivalent to area aP_ek. With the standard, owners of old plants enjoy greater rents--equivalent to area aP'_ef. The regulation thus results in a transfer from consumers' to producers' surplus of $P_eP'_e$fk. This transfer cannot appropriately be considered a cost of the regulation.

This situation changes, however, over a sufficiently long period of time, the actual length of which cannot be determined in this analysis. Over time, the number of old plants that continue to produce diminishes. This might occur, for example, as the unit operating costs of the deteriorating plants rise above market price P'_e.[108] As old plants retire, they are replaced by new plants subject to the NSPS. Eventually then, what had been a transfer from consumers' to producers' surplus becomes a real resource cost of the regulation.

To summarize, the total cost of the NSPS is comprised of three components in the long run: the new plant real resource cost, the deadweight loss in consumers' surplus, and the old plant real resource cost. In the very long run, the new plant real resource cost component increases as old plants are replaced by new ones and the total cost of the regulation in any given year is equivalent to the total reduction in consumers' surplus represented by area $P_eP'_e$dc in figure 9-5.

The analytical framework described above is used to calculate the total cost of each regulatory alternative for each model plant. Two estimates of the total cost of each regulation are computed: (1) the long-run estimates which include the new plant real resource cost, the deadweight loss in consumers' surplus, and the old plant real resource cost, and (2) the very long-run estimate which is the sum of the long-run estimate and the real resource cost of new plants that replace retiring old capacity.

The total annual cost of the regulation is estimated for 1987 assuming that the long-run, not the very long-run, market will have attained by that time. The total cost of the regulation presented for 1987 is thus equivalent to area kfdc in figure 9-5. The long-run baseline equilibrium price (P_e) is the ATC of producing one Mg of steel billets in a given model plant meeting regulatory alternative 1. This price is assumed to prevail in 1987 in the absence of new standards. The baseline equilibrium output (Q_e) is based on the steel projections in section 9.1.5.4. The new equilibrium market price (P'_e) under a proposed standard is the ATC of making steel in the EAF plant meeting the standard. A new equilibrium output (Q'_e) results given a demand elasticity of -1.86. The baseline output in 1987 from plants existing in 1981 (Q_o) is based on the projections section 9.1.5.4. This output is presumed to be forthcoming given P_e. An estimate of output from existing plants given the higher market price (P_e') due to the proposed standard (Q_o') is calculated using a supply elasticity of 2.16.[109]

Using the estimates of P_e, P_e', Q_e, Q_e', Q_o and Q_o', it is possible to estimate the 1987 total regulatory cost equivalent to area kfdc for each alternative assuming each model plant is the "price-setting" plant. The formulas used to calculate each component of the cost of the regulation are:

- New Plant Real Resource Cost
  = area gfdh
  = (Pé-Pe) (Qé-Qó);
- Deadweight Loss In Consumers' Surplus
  = area hdc
  = ½ (Pé-Pe) (Qe-Qé);
- Old Plant Real Resource Cost
  = area kfg
  = ½ (Pé-Pe) (Qó-Qo);
- Total Cost of Regulation
  = area kfdc
  = gfdh + hdc + kfg.

Estimates of the total cost of regulatory alternative 2 in 1987 are reported in Table 9-41. Estimates for specialty steel shops vary from $0.216 million for model plants 8 and 10 to a high of $0.773 million for model plant 7. Estimates of the total cost of alternative 2 for carbon shops vary from a low of $0.608 million for model plant 4 to a high of $1.096 million for model plant 2. The new plant real resource cost regularly comprises the major part of the total cost of the regulation in this long run period.

Greater total costs are associated with regulatory alternative 3. Table 9-42 indicates that total costs for carbon plants vary between $1.415 million and $2.666 million, excluding the negative costs for model plants 1 and 6 with a total furnace enclosure. Total costs for specialty steel plants range from 0.802 to $1.160 million.

In the very long run, all plants that are producing steel today will have been retired. As output from these existing plants declines, it will be replaced by output from new plants. It is difficult to speculate whether EAF plants will continue in the very long run to be the best technology.

TABLE 9-41. TOTAL COST OF REGULATORY ALTERNATIVE 2 IN 1987[a]

Model Plant	New Plant Real Resource Cost	Deadweight Loss In Consumers' Surplus	Old Plant Real Resource Cost	Total Cost Of Regulation
	10^6 1981 $			
1	0.696	0.011	0.006	0.713
1[b]	na	na	na	na
2	1.049	0.026	0.021	1.096
3	0.682	0.013	0.011	0.706
4	0.592	0.008	0.008	0.608
5	0.723	0.016	0.013	0.752
6	0.786	0.015	0.008	0.809
6[b]	na	na	na	na
7	0.737	0.020	0.016	0.773
8	0.213	0.002	0.001	0.216
9	0.338	0.005	0.005	0.348
10	0.213	0.002	0.001	0.216

[a] Model parameters: Q_e = 101.7×10^6 Mg (carbon)
= 18.0×10^6 Mg (specialty)
Q_o = 96.5×10^6 Mg (carbon)
= 17.0×10^6 Mg (specialty)

[b] Total Furnace Enclosure Option.

NOTE: na = not applicable.

TABLE 9-42. TOTAL COST OF REGULATORY ALTERNATIVE 3 IN 1987[a]

Model Plant	New Plant Real Resource Cost	Deadweight Loss In Consumers' Surplus	Old Plant Real Resource Cost	Total Cost Of Regulation
	10^6 1981 $			
1	2.077	0.133	0.363	2.573
1[b]	-4.422	-0.122	-0.426	-4.970
2	1.691	0.056	0.061	1.808
3	1.780	0.150	0.260	2.190
4	1.269	0.051	0.095	1.415
5	1.818	0.178	0.272	2.288
6	2.108	0.158	0.400	2.666
6[b]	-4.549	-0.024	-0.483	-5.056
7	0.230	0.125	0.805	1.160
8	0.572	0.037	0.207	0.816
9	0.562	0.043	0.216	0.821
10	0.562	0.042	0.198	0.802

[a] Model parameters:
$Q_e = 101.7 \times 10^6$ Mg (carbon)
$= 18.0 \times 10^6$ Mg (specialty)
$Qo = 96.5 \times 10^6$ Mg (carbon)
$= 17.0 \times 10^6$ Mg (specialty)

[b] Total furnace enclosure option.

However, if they do, the new plant real resource cost will increase by an amount equal to the area $P_eP'_efk$ in figure 9-5. This occurs because new, replacement plants are (presumably) subject to the standard indefinitely.

To approximate the annual, very long-run total cost of the regulation, area $P_eP'_edc$ is computed for 1987. The formula is: Total Cost In The Very Long Run = (Pé-Pe) Qé + ½ (Pé-Pe) (Qe-Qé). This is an underestimate of the long run total cost if in fact demand should shift rightward beyond D during the projection period. The estimates are valuable because they emphasize that in the very long run, the total decrease in consumers' surplus, equivalent to the entire area under the demand curve between the regulated and the unregulated prices, becomes a real resource cost of the regulation.

Table 9-43 reports the total cost estimates for alternatives 2 and 3 in the very long run. For regulatory alternative 2, the estimates range from a low of $12.195 million to a high of $22.347 million for carbon steel plants and from $3.958 million to $14.560 million for specialty steel plants. These very long run annual costs of regulation are considerably higher than the costs net of replacement plant real resource costs. Under regulatory alternative 3, the maximum cost estimate is $62.896 million for model plant 6 (without total furnace enclosure).

Model plants 4 and 7 are believed to best typify future plant construction. The anticipated 1987 total cost of regulatory alternative 2 is thus $0.608 million for carbon plants and $0.773 million for specialty plants for a total cost of $1.381 million. The anticipated 1987 total cost of alternative 3 is $1.415 million for carbon plants and $1.160 million for specialty plants for a total of $2.575 million. These 1987 anticipated regulatory cost estimates are calculated assuming long-run, not very long-run, market conditions prevailing in that year. That is, these estimates do not include the real resource cost incurred as new, controlled plants eventually retire old, uncontrolled plants.

TABLE 9-43. TOTAL COST OF REGULATORY ALTERNATIVES IN THE VERY LONG RUN[a]

Model Plant	10^6 1981 $ Regulatory Alternative 2	 3
1	14.228	59.871
1[b]	na	-65.453
2	22.347	37.574
3	14.226	50.700
4	12.195	30.459
5	15.240	53.724
6	16.257	62.896
6[b]	na	-69.228
7	14.560	37.494
8	3.958	19.043
9	6.474	19.784
10	3.958	18.679

[a] Based on projected 1987 demand conditions.

[b] Total furnace enclosure option.

NOTE: na = not applicable.

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APPENDIX A.

EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

Standards of performance for electric arc furnaces (EAF's) in the steel industry were promulgated in October 1974. The four-year review of these standards, required by Section 111(b) of the Clean Air Act as amended August 1977, was initiated by EPA in March 1979. Based on the results of an initial study, the decision was reached to pursue development of a Background Information Document (BID) to determine if revision of the standards was necessary.

In April 1980, an effort was begun to obtain the information needed to develop the BID. This information gathering has included literature surveys; canvassing of State, regional, and local air pollution control agencies; plant visits; meetings with industry representatives and associations; contact with engineering consultants and equipment vendors; and emission source testing. Significant events relating to the evolution of the BID are itemized in Table A-1.

TABLE A-1. EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

Date	Company, consultant, or agency/ Location	Nature of action
10/79	U.S. Environmental Protection Agency Research Traingle Park, N.C.	"Review of Standards of Performance for Electric Arc Furnaces in Steel Industry" published.
04/21/80	U.S. Environmental Protection Agency Research Triangle Park, N.C.	*Federal Register* announcement of notice of intent to explore revision of existing standards
06/13/80	Jones and Laughlin Steel Corporation Pittsburgh, Pa.	Section 114 letter
06/23-26/80	Jones and Laughlin Steel Corporation Pittsburgh, Pa.	Observation of emission test
06/25/80	Florida Steel Corporation Charlotte, N.C.	Section 114 letter
07/02/80	Allegheny Ludlum Steel Corporation Brackenridge, Pa.	Section 114 letter
07/02/80	Armco, Incorporated Butler, Pa.	Section 114 letter
07/02/80	Washington Steel Company Washington, Pa.	Section 114 letter
07/10/80	AL Tech Specialty Steel Corporation Watervliet, N.Y.	Section 114 letter
07/10/80	Colt Industries, Incorporated Syracuse, N.Y.	Section 114 letter
07/15/80	Allegheny Ludlum Steel Corporation Brackenridge, Pa.	Site visit
07/16/80	Armco, Incorporated Butler, Pa.	Site visit
07/22/70	Washington Steel Company Washington, Pa.	Site visit
07/23/80	AL Tech Specialty Steel Corporation Watervliet, N.Y.	Site visit
07/24/80	Colt Industries, Incorporated Syracuse, N.Y.	Site visit

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/ Location	Nature of action
08/05/80	Florida Steel Corporation Charlotte, N.C.	Site visit
08/28/80	American Iron and Steel Institute Durham, N.C.	Meeting to discuss project
09/10/80	Eastern Stainless Steel Company Baltimore, Md.	Section 114 letter
09/10/80	Ford Motor Company Dearborn, Mich.	Section 114 letter
09/23/80	Ford Motor Company Dearborn, Mich.	Site visit
09/24/80	Eastern Stainless Steel Company Baltimore, Md.	Site visit
10/02/80	AL Tech Specialty Steel Corporation Watervliet, N.Y.	Section 114 letter
10/02/80	Colt Industries, Incorporated Syracuse, N.Y.	Section 114 letter
10/08/80	Colt Industries, Incorporated Syracuse, N.Y.	Pretest survey
10/09/80	AL Tech Specialty Steel Corporation Watervliet, N.Y.	Pretest survey
10/15/80	Babcock and Wilcox Company Beaver Falls, Pa.	Section 114 letter
10/15/80	North Star Steel Company Monroe, Mich.	Section 114 letter
10/21/80	Interlake Incorporated Riverdale, Ill.	Section 114 letter
10/21/80	Roblin Steel Company North Tonawanda, N.Y.	Section 114 letter
10/23/80	North Star Steel Company Monroe, Mich.	Site visit
10/24/80	Babcock and Wilcox Company Beaver Falls, Pa.	Site visit
10/24/80	Eastern Stainless Steel Company Baltimore, Md.	Section 114 letter
10/28/80	Eastern Stainless Steel Company Baltimore, Md.	Pretest survey

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/ Location	Nature of action
11/10-11/80	Hoeganaes Corporation Gallatin, Tenn.	Observation of emission test
11/25/80	Colt Industries, Incorporated Midland, Pa.	Section 114 letter
11/25/80	North Star Steel Company St. Paul, Minn.	Section 114 letter
11/25/80	Republic Steel Corporation Cleveland, Ohio	Section 114 letter
11/25/80	Sharon Steel Corporation Farrell, Pa.	Section 114 letter
11/25/80	Northwestern Steel and Wire Company Sterling, Ill.	Section 114 letter
11/25/80	Nucor Steel Corporation Darlington, S.C.	Section 114 letter
11/25/80	Raritan River Steel Company Perth Amboy, N.J.	Section 114 letter
12/09/80	Eastern Stainless Steel Company Baltimore, Md.	Section 114 letter
12/09/80	North Star Steel Company Monroe, Mich.	Section 114 letter
12/16/80	AL Tech Specialty Steel Corporation Watervliet, N.Y.	Section 114 letter
12/17-18/80	Eastern Stainless Steel Company Baltimore, Md.	Visible emission source test
12/18-19/80	North Star Steel Company Monroe, Mich.	Observation of emission test
01/20/81	Carpenter Technology Corporation Reading, Pa.	Section 114 letter
01/22/81	Carpenter Technology Corporation Reading, Pa.	Pretest survey
02/17/81	American Iron and Steel Institute Washington, D.C.	Request for information on opacity monitors
02/17/81	U.S. Steel Corporation Pittsburgh, Pa.	Section 114 letter
02/19/81	Andersen Samplers, Incorporated Altanta, Ga.	Request for information on opacity monitors

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/ Location	Nature of action
02/19/81	Bethlehem Steel Corporation Los Angeles, Calif.	Section 114 letter
02/19/81	Chaparral Steel Corporation Midlothian, Tex.	Section 114 letter
02/19/81	Contraves Goerz Corporation Pittsburgh, Pa.	Request for information on opacity monitors
02/19/81	Datatest, Incorporated Levittown, Pa.	Request for information on opacity monitors
02/19/81	Dynatron, Incorporated Wallingford, Conn.	Request for information on opacity monitors
02/19/81	Environmental Data Corporation Monrovia, Calif.	Request for information on opacity monitors
02/19/81	Lear Siegler, Incorporated Englewood, Colo.	Request for information on opacity monitors
02/24/81	Atlantic Steel Company Atlanta, Ga.	Section 114 letter
03/02-03/81	Chaparral Steel Corporation Midlothian, Tex.	Visible emission source test
03/05-06/81	U.S. Steel Corporation Baytown, Tex.	Visible emission source test
03/11-12/81	Atlantic Steel Company Cartersville, Ga.	Visible emission source test
03/25/81	Sholtes and Koogler Gainesville, Fla.	Request for information on opacity monitors
04/06-09/81	AL Tech Specialy Steel Corporation Watervliet, N.Y.	Emission source test
04/21/81	Bethlehem Steel Corporation Los Angeles, Calif.	Section 114 letter
04/23/81	Carpenter Technology Corporation Reading, Pa.	Section 114 letter
04/27-30/81	Carpenter Technology Corporation Reading, Pa.	Emission source test
05/05-06/81	Bethlehem Steel Corporation Los Angeles, Calif.	Visible emission source test
07/22/81	Roblin Steel Company North Tonawanda, N.Y.	Section 114 letter

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/ Location	Nature of action
08/18/81	American Iron and Steel Institute Washington, D.C.	Request for information on EAF's
09/30/81	Al Tech Specialty Steel Corporation Watervliet, N.Y.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Allegheny Ludlum Steel Corporation Brackenridge, Pa.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	American Iron and Steel Institute Washington, D.C.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Armco, Incorporated Butler, Pa.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Atlantic Steel Company Atlanta, Ga.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Bethlehem Steel Corporation Los Angeles, Calif.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Carpenter Technology Corporation Reading, Pa.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Chaparral Steel Corporation Midlothian, Tex.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Eastern Stainless Steel Company Baltimore, Md.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Sholtes and Koogler Gainesville, Fla.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Ferrco Engineering, Limited Whitby, Ontario, Can.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Ford Motor Company Dearborn, Mich.	Request for comment on draft BID Chapters 3, 4, 5, and 6

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/ Location	Nature of action
09/30/81	Interlake, Incorporated Riverdale, Ill.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Jones and Laughlin Steel Corporation Pittsburgh, Pa.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	North Star Steel Company Monroe, Mich.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	North Star Steel Company St. Paul, Minn.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Nucor Steel Corporation Darlington, S.C.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Obenchain Calumet Corporation Gary, Ind.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Pennsylvania Engineering Corporation Pittsburgh, Pa.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Raritan River Steel Perth Amboy, N.J.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Roblin Steel Company North Tonawanda, N.Y.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Union Carbide Corporation Danbury, Conn.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Union Carbide Corporation Tarrytown, N.Y.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	U.S. Steel Corporation Pittsburgh, Pa.	Request for comment on draft BID Chapters 3, 4, 5, and 6
09/30/81	Washington Steel Company Washington, Pa.	Request for comment on draft BID Chapters 3, 4, 5, and 6

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/ Location	Nature of action
10/13/81	Colt Industries, Incorporated Midland, Pa.	Section 114 letter
10/19-20/81	Colt Industries, Incorporated Midland, Pa.	Observation of emission test
10/21-23/81	Roblin Steel Company Durkirk, N.Y.	Observation of emission test
11/05/81	American Iron and Steel Institute Durham, N.C.	Meeting to discuss project
12/11/81	Kaiser Steel Corporation Fontana, Calif.	Request for comment on draft BID Chapters 3, 4, 5, 6, 7, and 8
01/06/82	Bayou Steel Corporation LaPlace, La.	Section 114 letter
01/12/82	Hatch Associates, Limited Toronto, Ontario, Can.	Request for comment on draft BID Chapters 3, 4, 5, and 6
02/03/82	Carpenter Technology Corporation Reading, Pa.	Section 114 letter
02/03/82	Jones and Laughlin Steel Corporation Pittsburgh, Pa.	Section 114 letter
02/10/82	Carpenter Technology Corporation Reading, Pa.	Visible emission source test
02/18/82	Atlantic Steel Company Atlanta, Ga.	Section 114 letter
02/24/82	Atlantic Steel Company Cartersville, Ga.	Site visit
03/09-10/82	Jones and Laughlin Steel Corporation Pittsburgh, Pa.	Visible emission source test
04/06/82	Dr. Sholtes, Sholtes and Koogler, Environmental Consultants Durham, N.C.	Meeting to discuss project
07/21-22/82	National Air Pollution Control Techniques Advisory Committee Dallas, Texas	Meeting to discuss recommended standard
07/23/82	Chaparral Steel Company Midlothian, Texas	Site visit

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/ Location	Nature of action
08/06/82	Dr. Sholtes, Sholtes and Koogler, Environmental Consultants Durham, N.C.	Meeting to discuss project
08/12/82	Chaparral Steel Company Midlothian, Texas	Section 114 letter
08/23-24/82	Chaparral Steel Company Midlothian, Texas	Visible emission source test

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

This appendix consists of a reference system, cross-indexed with the October 21, 1974, Federal Register (39 FR 37419) containing the Agency guidelines concerning the preparation of environmental impact statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the Federal Register guidelines.

TABLE B-1. CROSS-INDEXED REFERENCE SYSTEM TO HIGHLIGHT ENVIRONMENTAL IMPACT PORTIONS OF THE DOCUMENT

Agency guidelines for preparing regulatory action environmental impact statements (39 FR 37419)	Location within the Background Information Document
1. BACKGROUND AND SUMMARY OF REGULATORY ALTERNATIVES	
Summary of regulatory alternatives	The regulatory alternatives from which standards will be chosen for proposal are summarized in Chapter 1, Section 1.1.
Statutory basis for proposing standards	The statutory basis for proposing standards is summarized in Chapter 2, Section 2.1.
Relationship to other regulatory agency actions	The relationships between the regulatory agency actions are discussed in Chapters 3, 7, and 8.
Industry affected by the regulatory alternatives	A discussion of the industry affected by the regulatory alternatives is presented in Chapter 3, Section 3.1. Further details covering the business and economic nature of the industry are presented in Chapter 9, Section 9.2.
Specific processes affected by the regulatory alternatives	The specific processes and facilities affected by the regulatory alternatives are summarized in Chapter 1, Section 1.1. A detailed technical discussion of the processes affected by the regulatory alternatives is presented in Chapter 3, Section 3.2.
2. REGULATORY ALTERNATIVES	
Control techniques	The alternative control techniques are discussed in Chapter 4, Sections 4.2, 4.3, 4.4, and 4.5.

(continued)

TABLE B-1 (continued)

Agency guidelines for preparing regulatory action environmental impact statements (39 FR 37419)	Location within the Background Information Document
Regulatory alternatives	The various regulatory alternatives, including "no additional regulatory action," are defined in Chapter 6, Section 6.2. A summary of the major alternatives considered is included in Chapter 1, Section 1.1.
3. ENVIRONMENTAL IMPACT OF THE REGULATORY ALTERNATIVES	
Primary impacts directly attributable to the regulatory alternatives	The primary impacts on mass emissions and ambient air quality due to the alternative control systems are discussed in Chapter 7, Sections 7.1, 7.2, 7.3, 7.4, and 7.5. A matrix summarizing the environmental impacts is included in Chapter 1.
Secondary or induced impacts	Secondary impacts for the various regulatory alternatives are discussed in Chapter 7, Sections 7.1, 7.2, 7.3, 7.4, and 7.5.
4. OTHER CONSIDERATIONS	A summary of the potential adverse environmental impacts associated with the regulatory alternatives is included in Chapter 1, Section 1.2, and Chapter 7. Potential socio-economic and inflationary impacts are discussed in Chapter 9, Section 9.3. Irreversible and irretrievable commitments of resources are discussed in Chapter 7, Section 7.6.

APPENDIX C. EMISSION TEST DATA FOR FABRIC FILTERS ON ELECTRIC ARC FURNACES AND ARGON-OXYGEN DECARBURIZATION VESSELS IN THE STEEL INDUSTRY

This appendix presents the available emission test data for steel industry electric arc furnaces (EAF's) and argon-oxygen decarburization (AOD) vessels. The particulate matter emission data and visible emission (VE) observations for carbon steel plants are presented in Section C.1. Section C.2 presents the particulate matter emission data and VE observations for EAF's and AOD vessels in the specialty steel segment of the steel industry. Section C.3 presents the available VE data for the dust-handling systems at both carbon and specialty steel shops.

The particulate matter emission data presented in this appendix were obtained using Reference Method 5 and draft Reference Method 5D. Draft Reference Method 5D involves the use of a Method 5 sampling train to sample sites that do not meet Reference Method 1 criteria. Discussion of this test method is presented in Appendix D. The visible emissions data presented in this appendix were obtained using Reference Methods 9 and 22 and continuous opacity monitors. Table C-1 contains a summary of the data from, and information about, the 15 carbon steel shops and 4 specialty steel shops that are presented in this appendix.

Another test method that has been used to sample EAF and AOD vessel emissions from fabric filters involves the use of high volume (hi-vol) samplers, which are commonly used for ambient air sampling. However, the hi-vol sampling method is not recommended by EPA because there are problems with the sampling methodology. Although the hi-vol method was used at several steel mills to determine compliance with applicable State and Federal regulations, the hi-vol data will not be used in determining any revisions to the standard.

C.1 EMISSION TEST DATA FOR FABRIC FILTERS ON ELECTRIC ARC FURNACES IN THE CARBON STEEL INDUSTRY

C.1.1 Particulate Matter and Visible Emissions

This section provides a summary of particulate matter emission sampling conducted at eight carbon steel shops. The exhaust concentration of particulate matter emissions was measured at Plants A through H by Reference Method 5. The emission data on these plants are summarized in Figure C-1. In addition, the concentration of particulate matter emissions was measured by the hi-vol sampling technique at six plants; however, the data will not be used in support of a standard.

The VE observations were made using Method 9. The VE data from fabric filters on plants with best demonstrated control technology, Plants B, C, F, G, H, I, J, and K, are summarized in Table C-2. The available VE data from shop roof monitors on Plants C, G, H, I, J, and K are summarized in Table C-3.

C.1.1.1 Plant A. Plant A has two furnaces; one of 45.4-megagram (Mg) (50-ton) melting capacity and the other of 68-Mg (75-ton) melting capacity. The heat lengths vary from 4 to 8 hours depending on the grade of steel produced. The emissions from the furnaces are captured by a canopy built into the shop roof. The shop roof is closed so the hoods above the furnaces act to evacuate the melt shop fully, and the two canopy hoods are connected to a common duct leading to the fabric filter. A single positive-pressure fabric filter rated at 217 cubic meters per second (m^3/s) (460,000 actual cubic feet per minute [acfm]) flow rate is used to clean the exhaust gases.[1] The 12-compartment fabric filter is equipped with Type 55 Dacron® filter bags and has a net air-to-cloth ratio of 3.2:1.[2] The pressure drop across the bags is 0.87 to 1.02 kilopascals (kPa) (3.5 to 4.1 inches [in.] water gauge [w.g.]).

The fabric filter has six stub stacks of which three were sampled for particulate matter emissions. The plant was operating near design capacity during the tests, and the control system was operating normally. Three 4-hour tests were performed at the inlet duct upstream of the fans and at three of the fabric filter outlet stacks. The emissions were

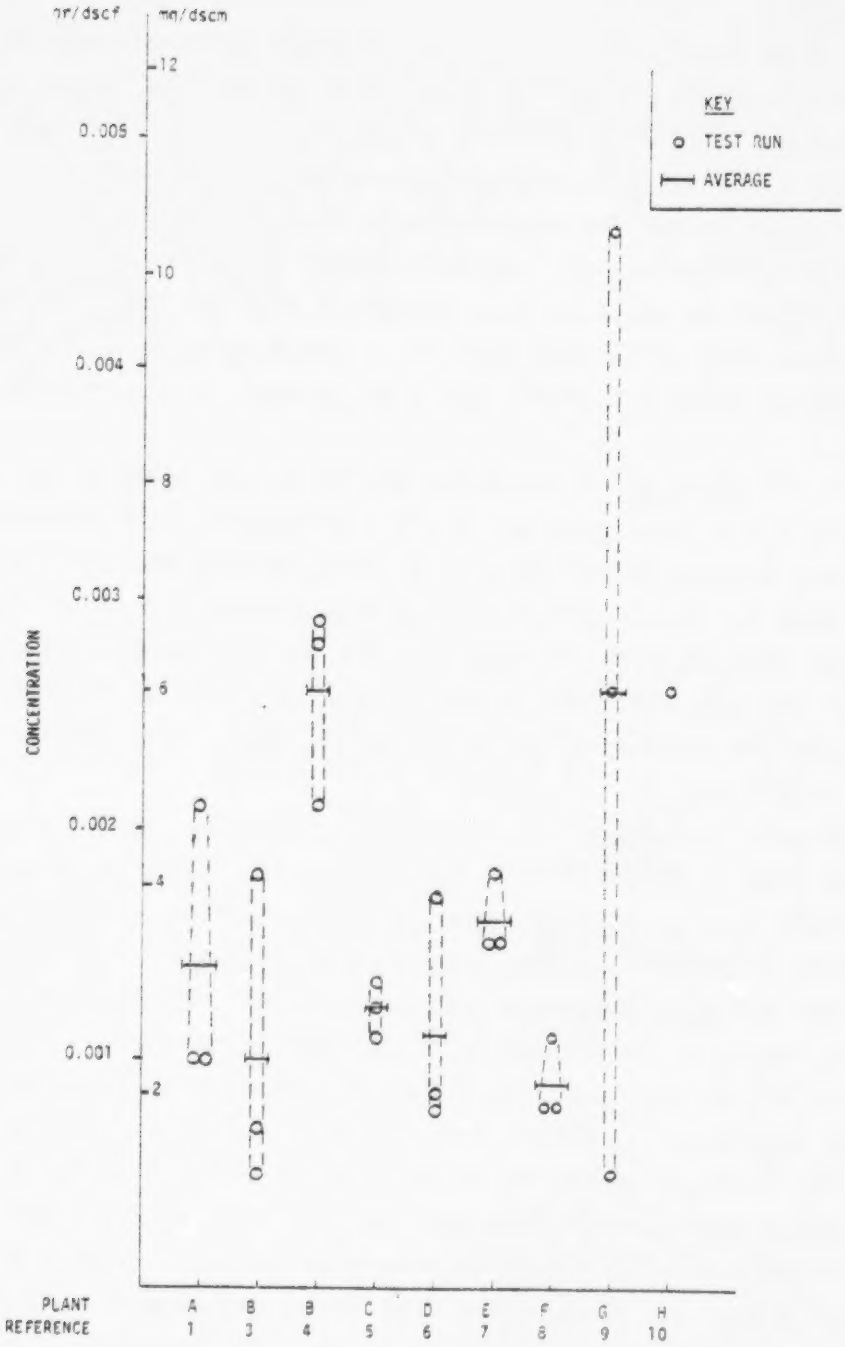

Figure C-1. Summary of particulate matter source test data from fabric filters on EAF's at carbon steel shops.

measured using Method 5 (with the single exception that the probe was not heated).

Detailed results of the particulate matter emission tests are presented in Tables C-4 and C-5. The inlet particulate matter concentrations determined from the three samples were 91.0, 136.9, and 141.7 milligrams per dry standard cubic meter (mg/dscm) (0.0397, 0.0597, and 0.0618 grains per dry standard cubic foot [gr/dscf]), with an average inlet concentration of 123.1 mg/dscm (0.0537 gr/dscf). The outlet particulate matter emission data determined from the three samples on three of the six stacks were 4.81, 2.21, and 2.29 mg/dscm, averaging 3.11 mg/dscm (0.0021, 0.00097, and 0.001 gr/dscf, averaging 0.0014 gr/dscf).[1]

C.1.1.2 Plant B. Plant B has two EAF'S, one rated at 22.7 Mg (25 tons) and another rated at 36.3 Mg (40 tons).[3] Each furnace has a side draft hood to capture emissions during melting and refining. A canopy hood is located directly above each furnace to capture fugitive emissions from charging and tapping. The roof of the shop is closed; however, the side walls on the shop extend to within 10 feet of the ground and the two ends of the building are open. This creates crossdrafts within the shop.

The emissions from both furnaces are controlled by two negative-pressure fabric filters (Nos. 3 and 4). Fabric filter No. 3 serves the side draft hoods on both furnaces during the melting and refining phases of a heat. Fabric filter No. 4 is designed to control the fugitive emissions that are captured by the canopy hoods. During charging and tapping, the air flow through the side draft hoods and fabric filter No. 3 is redirected automatically to the canopy hoods above each furnace, thereby supplementing the air flow to fabric filter No. 4. Fabric filter No. 3 has 14 compartments and is rated at 62.2 m^3/s (132,000 acfm) flow rate with a gross air-to-cloth ratio of 2.37:1. Fabric filter No. 4 is rated at 42.9 m^3/s (91,000 acfm) flow rate and has a gross air-to-cloth ratio of 2.69:1.[11] The pressure drop across the bags in both fabric filters is 1.01 to 2.7 kPa (4 to 11 in. w.g.)[11] Both fabric filters are equipped with Dacron® polyester bags that are cleaned with a shaker-type mechanism.

The emission tests were run on the new 36.3-Mg (40-ton) EAF, which is subject to the existing NSPS. The existing 22.7-Mg (25-ton) EAF was not operated during the emission tests. The fabric filters were tested using a Reference Method 5 sampling train. The furnace was operating at design capacity during the emission tests. During the tests, opacity monitors on each of the fabric filters were in operation and in the process of certification tests. Opacity readings were made of the emissions from the shop roof monitor and the dust-handling equipment.

Detailed results of the tests are presented in Tables C-6 and C-7. The particulate matter concentrations for fabric filter No. 4 were 1.60, 1.15, and 4.12 mg/dscm, averaging 2.29 mg/dscm (0.0007, 0.0005, and 0.0018 gr/dscf, averaging 0.0010 gr/dscf).[3] The particulate matter concentrations for fabric filter No. 3 were 6.41, 6.64, and 4.81 mg/dscm, averaging 5.95 mg/dscm (0.0028, 0.0029, and 0.0021 gr/dscf, averaging 0.0026 gr/dscf).[4]

The VE data from the fabric filters were obtained with a continuous opacity monitor. The average opacity from the fabric filter continuous opacity monitor at Plant B was 2.5 percent.[3] The VE data for the shop roof monitor will not be used to support a standard because the shop walls at Plant B do not extend to ground level. This arrangement of the shop walls creates cross-draft problems, which reduces the capture device efficiency and causes opacities of the emissions from the shop roof monitor to be higher than those from shops in which the walls extend to ground level.

C.1.1.3 Plant C. Plant C operates one 49.9-Mg (55-ton) EAF.[5] Particulate matter emissions from the furnace are captured by a total furnace enclosure (TFE), a local tapping hood, and an overhead canopy hood. The TFE captures the melting and refining emissions and most of the charging emissions. During charging, the TFE doors close, and an air curtain, which aids in the capture of the charging emissions, blows across the enclosure opening provided for the crane cables. The fugitive emissions that escape the TFE during charging are captured by the overhead canopy hood. The tapping hood is located below the EAF and captures the emissions from the tapping operation. In addition, there is a tundish lancing hood located beside the tapping area that is ducted to the same control device as the TFE and tapping hood. (The molten steel is poured from the ladle to the continuous caster through a tundish. The tundish is lanced with oxygen to remove any solidified metal.)

The emissions from the EAF are controlled by a negative-pressure fabric filter. The fabric filter is rated at a 70.8-m^3/s (150,000-acfm) flow rate and has a gross air-to-cloth ratio of 4.5:1.[12] The polyester bags are cleaned by reverse air flow. The pressure drop across the bags is maintained between 0.50 to 1.74 kPa (2 to 7 in. w.g.).

Grain loadings from the fabric filter outlet were measured using Reference Method 5 to determine compliance with the existing NSPS for EAF's. The fabric filter operated normally and the EAF was operating at full capacity during the emission test. Visible emission readings were taken of the fabric filter stack and the building roof.

The building roof is closed; however, one end of the shop is open to facilitate scrap transport. The fugitive emissions from all processes within the building (furnace operation, tundish lancing, casting, slag removal, etc.) mix and slowly drift out the open end of the shop.[12] This created difficulties in reading VE's because of the time lag between the release of emissions from a particular furnace operation and the observation of visible emissions. For example, emissions from the removal of slag by the bulldozer would mix with furnace emissions and distort the visible emission readings. Efforts were made to distinguish between the emissions from different sources, and only opacities of the emissions from the furnace operation were read.

Two tests were performed at Plant C. The first test was not accepted by the State due to problems with the Reference Method 5 test. Therefore, only the particulate data from second test will be presented. The visible emission data obtained during both tests will be presented. During the second test, visible emission observations were made of the dust-handling system.

Three Reference Method 5 sampling runs were performed with the first test run covering two full heats, and the other two test runs each covering one full heat. The particulate matter concentrations from the three samples were 3.05, 2.52, and 2.79 mg/dscm, averaging 2.79 mg/dscm (0.00133, 0.00110, and 0.00122 gr/dscf, averaging 0.00122 gr/dscf).[5] The sampling results are presented in Table C-8.

For the first test, the opacity of the emissions from the fabric filter outlet stack was always zero. A maximum 6-minute average opacity of 14.6 percent was observed from the end of the shop one time during a charge. This high opacity reading may have been the result of other plant operations, as it occurred when a front-end loader was removing slag near the furnace. The remainder of the visible emission readings were below 5 percent opacity for charging, melting, and tapping operations.

For the second test, no visible emissions were observed coming from the fabric filter outlet. The highest 6-minute average opacity observed from the melt shop was 5.2 percent, with a majority of the emissions being 0 percent opacity. Table C-3 summarizes the VE data for the two tests.

C.1.1.4 Plant D. Plant D operates one ultra-high power (UHP) EAF rated at a 108.8-Mg (120-ton) capacity.[6] The meltdown and refining emissions from the EAF are controlled by a direct-shell evacuation control (DEC) system that is ducted to a positive-pressure fabric filter. The DEC system has an independent fan that pushes the DEC exhaust to two main fans that serve the fabric filter. Fugitive emissions (i.e., those generated during charging and tapping and any emissions that are not captured by the DEC) are captured by an overhead canopy hood and ducted to the fabric filter. A retractable tundish lancing hood, which is only used periodically, is ducted to the same fabric filter along with the exhausts from the canopy hood. The melt shop roof at Plant D is closed.

The flow through the fabric filter is 200 m^3/s (425,000 acfm).[13] The polyester bags in the fabric filter are cleaned by reverse air. The pressure drop across the filter bags is 1.25 to 1.75 kPa (5 to 7 in. w.g.). The stack located above the fabric filter has a fan to supplement the two main fans and reduce the back pressure in the fabric filter compartments caused by the stack.

The fabric filter outlet was tested for particulate matter using Reference Method 5. The furnace was operating at design capacity during the tests. The fabric filter was operating without the stack booster fan during the test. The length of the EAF heat cycle varied during the tests from 1 hour and 30 minutes to 2 hours. The sampling was performed at four traverse points with 24 minutes of sampling time per traverse point, for a total sampling time of 96 minutes. The testing was peformed so that a sample representative of typical furnace operation was obtained; however, the sampling did not always begin at the time of the furnace charge.

Detailed results of the test are presented in Table C-9. The particulate matter concentrations from the three samples were 1.90, 3.82, and 1.99 mg/dscm, averaging 2.57 mg/dscm (0.00083, 0.00167, and 0.00087 gr/dscf, averaging 0.0011 gr/dscf).[13] Visible emissions could not be read by a certified reader during the test because of inclement weather.

C.1.1.5 Plant E. Plant E operates one UHP EAF rated at 117.9 Mg (130 tons), with an average heat time of 2.25 hours.[7] The EAF emissions are controlled by a positive-pressure fabric filter. The melting and refining emissions from the furnace are captured by a DEC system. The charging and tapping emissions are captured by an overhead canopy hood. The design air flow rate to the fabric filter is 198.2 m^3/s (420,000 acfm). The Dacron® polyester bags are exposed to a maximum temperature of 99°C (210°F), and the gross air-to-cloth ratio is 2.82:1.[14] Reverse air flow is used to clean the bags.

The emission compliance test at Plant E was run on the 3.7 x 5.5 meter (m) (12 x 18 foot [ft]) outlet on the side of the fabric filter. Reference Method 5 and hi-vol sampling tests were run simultaneously on the fabric filter outlet. The sampling times for the tests were approximately 4 hours and typically covered more than one full heat from tap to tap. The furnace and the fabric filter were operating normally during the test. The particulate matter emissions for the three Method 5 tests were 3.44, 3.44, and 4.12 mg/dscm, averaging 3.67 mg/dscm (0.0015, 0.0015, and 0.0018 gr/ dscf, averaging 0.0016 gr/dscf).[7] These results are presented in Table C-10. (The particulate matter emissions for the three hi-vol tests were 0.62, 0.73, and 0.62 mg/dscm, averaging 0.66 mg/dscm [0.00027, 0.00032, and 0.00027 gr/dscf, averaging 0.00029 gr/dscf].) Visible emissions from the shop roof monitor were not read during the test. An opacity monitor was in operation during the test on the outlet of the fabric filter. The average opacity of the exhaust gases during the test was reported as 3 percent; however, no data was presented to substantiate this.

C.1.1.6 Plant F. Plant F operates two 36.3-Mg (40-ton) and three 45.5-Mg (50-ton) EAF's. The test information presented here is for the three 45.4-Mg (50-ton) EAF's and the control system for these furnaces only will be discussed. The primary emissions from the EAF's are captured by side draft hoods and the fugitive emissions are captured by canopy hoods built into the roof trusses. The shop roof at this facility is closed. The side draft and canopy hoods are ducted together to a positive-pressure fabric filter that is rated at 349.2 m^3/s (740,000 acfm). The baghouse has 60 modules and a gross air-to-cloth ratio of 2.33:1.[8,15] The bags are cleaned by a shaker mechanism and the clean gases are vented out a 25.9-m (85-ft) tall metal stack with an inside diameter of 5.5 m (18 ft).

The fabric filter stack was tested following Reference Method 5 procedures. Three Reference Method 5 test runs were performed that covered heats from each of the three furnaces, which were operated on staggered schedules. Sampling results are presented in Table C-11. The particulate matter concentrations from the three samples were 1.83, 2.52, and 1.83 mg/dscm, averaging 2.06 mg/dscm (0.0008, 0.0011, and 0.0008 gr/dscf, averaging 0.0009 gr/dscf).[8] Eighteen minutes of visible emission observations were made of the baghouse stack during the test and all the opacity readings were 0 percent opacity. A continuous opacity monitor was in use at Plant F during the test. However, the monitor was not operating properly and no data were reported. No visible emission observations were reported for the melt shop roof.

C.1.1.7 Plant G. Plant G operates one EAF that is rated at 108.9 Mg (120 tons) per heat. The primary emissions from the EAF are captured by a DEC system, while the fugitive emissions are captured by an overhead canopy hood. The shop roof at Plant G is closed. The DEC and the canopy hood are ducted together to a positive-pressure fabric filter. The six-compartment fabric filter is rated at 188.8 m^3/s (400,000 acfm) and has a net air-to-cloth ratio of 2.60:1. The pressure drop across the compartment varies from 0.30 to 0.60 kPa (1.2 to 2.4 in. w.g.).

The fabric filter outlet, a 3.7 x 24.7 m (12 x 81 ft) monovent, was tested with a modified version of Reference Method 5. The modifications to the Method 5 procedure included: (1) traversing across the top of 2 of the 6 compartments per run (12 traverse points evenly spaced), (2) a longer sampling time to obtain a minimum sample volume of 4.5 dscm (160 dscf) as required by the NSPS regulation, and (3) a special procedure for setting the isokinetic sampling rate. This procedure was necessary due to flow disturbances in the baghouse outlet duct (i.e., a positive-pressure fabric filter monovent since the sampling site did not meet Method 1 criteria). The fabric filter operated normally during the test period. The particulate matter emissions for the three modified Method 5 tests were 10.6, 5.9, and 1.14 mg/dscm, averaging 5.9 mg/dscm (0.0046, 0.0026, and 0.0005 gr/dscf, averaging 0.0026 gr/dscf).[9] These results are presented in Table C-12. Visible emissions from the shop roof monitor were read during the test and the results were no visible emissions for 46 six-minute averaging periods. In addition, there was a continuous opacity monitor in operation with a 24.7-m (81-ft) path length across the monovent of the fabric filter. The highest 6-minute average opacity for all test runs was 2.8 percent. Visible emissions from the dust-handling equipment were also observed. However, because of high opacity readings, the equipment failed to meet compliance and will have to be improved. Table C-3 presents the VE data for Plant G.

C.1.1.8 Plant H. Plant H operates two 90.7-Mg (100-ton) EAF's and one 136.1-Mg (150-ton) EAF. The 136.1-Mg (150-ton) EAF was not in operation during the emission test. The furnaces average 4.5 hours tap-to-tap, with 30 minutes at the beginning of each heat spent on conditioning the furnace refractories. The process emissions are captured by DEC systems while the fugitive emissions are captured by canopy hoods above each furnace. The shop roof monitor at Plant H is open. The exhausts from the DEC systems are ducted to two positive-pressure fabric filters each rated at 66.1 m^3/s (140,000 acfm) at 135°C (275°F).[16] The fabric filters have an air-to-cloth ratio of 3:1 and vent the cleaned exhaust gases out a continuous roof monitor that is 1.5 m (5 ft) wide and 14.6 m (48 ft) long. The emissions captured by the canopy hoods are ducted to a single negative-pressure fabric filter with an air flow rate of 162.8 m^3/s (345,000 acfm) that vents out a stack. This fabric filter has an air-to-cloth ratio of 4:1.[16]

The outlet of one DEC fabric filter that controls one EAF was emission-tested with a Method 5 sampling train that was modified to use a calibrated hot wire anemometer instead of a pitot tube. Twenty-four sampling ports were installed in the vertical sheeting of the throat of the fabric filter roof monitor. Two sampling points were made at each port for a total of 48 separate points. One 4-hour sampling run was performed and the particulate matter emissions were 5.95 mg/dscm (0.0026 gr/dscf).[10] A summary of the results is presented in Table C-13.

The canopy hood fabric filter that serves all three furnaces was also tested. The 136.1-Mg (150-ton) furnace was not in operation during the test. The results of the Method 5 test were high due to reasons that are assignable, and the results from this fabric filter will not be used in the development of the standard.

Visible emissions readings were taken from the melt shop roof and the canopy hood fabric filter. A total of 10 hours and 58 minutes of observations were made of the melt shop roof. Eighty-six percent of the emissions had zero percent opacity, however the charges and taps were higher. The highest opacity based on a 6-minute average for a charge was 12 percent and the highest for a tap was 33 percent.[10] During the test period, 2 hours of visible emission readings were made of the canopy hood fabric filter and the result was 0 percent opacity. Table C-3 presents the summarized VE data for this plant.

C.1.1.9 Plant I. Plant I operates two EAF's each with a rated capacity of 108.9 Mg (120 tons). The process emissions from both furnaces are captured by a DEC system, while the fugitive emissions are captured by an overhead canopy hood. The shop roof at Plant I is closed to prevent fugitive emissions from escaping the building. The emissions captured by the DEC systems on each furnace are ducted to a 12-compartment fabric filter that operates at 34.9 m^3/s (74,000 acfm). The fabric filter is equipped with silicone-treated glass bags that are cleaned by reverse air. The inlet temperature to the fabric filter varies from 177° to 232°C (350° to 450°F).[16] The emissions from the canopy hood are ducted to a separate 14-compartment fabric filter. The total air flow to this fabric filter is 330 m^3/s (700,000 acfm) except during charging and tapping operations when the control dampers are fully open and the maximum flow is 533 m^3/s (1,130,000 acfm).[16] This fabric filter is equipped with Dacron® polyester bags that are cleaned by a shaking mechanism.

Visible emission readings were taken at this plant from both fabric filters and the shop roof. One hour of visible emissions were read from the DEC baghouse that all exhibited 0 percent opacity. Visible emissions from the canopy hood fabric filter were also observed for one hour. This fabric filter exhibited puffs of approximately 5 seconds in duration that appeared to coincide with compartment cleaning. These puffs indicate that the fabric filter is not representative of a well-maintained and operated fabric filter and that data will not be used to support a standard. An hour of visible emission readings was also taken of the melt shop roof. All the readings exhibited 0 percent opacity. Table C-3 presents the summarized VE data for this plant.

C.1.1.10 Plant J. Plant J has two UHP furnaces, and each produces 317.5 Mg (350 tons) of molten steel per heat.[17] The two furnaces were retrofitted into an existing open hearth shop, and their emissions are controlled by a new fabric filter. The majority of the meltdown and refining emissions are captured by a DEC system. The tapping emissions are captured by a tapping hood situated above the tapping platform that supports the ladle. The slagging emissions are captured by a close-fitting slagging hood. The charging emissions and any fugitive emissions that escape the DEC or tapping hood are captured by an overhead canopy hood. The shop roof monitor is closed over the furnaces and open elsewhere. The design flow rate for the fabric filter is 445.9 m^3/s (945,000 acfm), and the gross air-to-cloth ratio is 3:1. The pressure drop across the fabric filter bags is 0.75 to 1.87 kPa (3 to 7.5 in. w.g.).[18] The fabric filter is equipped with Nomex® bags, which are cleaned by a mechanical shaker. The fabric filter exhausts through a continuous ridge ventilator.

The emission compliance test was conducted with hi-vol samplers; therefore, the particulate emission data are not presented.

Concurrent with the fabric filter sampling, visible emission data were obtained from the baghouse and the shop roof monitor. The maximum 6-minute average visible emission reading during a tap that was attributable to the EAF's was 5.0 percent.[19] The highest opacity reading during a charge that was attributable to an EAF was 4.4 percent. The highest shop roof opacity reading during EAF melting and refining was 4.2 percent. Plant personnel have indicated that the closed roof monitor area above the furnaces has been extended (thus eliminating the open area) in order to reduce the noise problem and to contain the fugitive emissions to obtain the desired shop roof opacity of 0 percent. A total of 96 six-minute averages that are between 0 and 5 percent opacity were recorded during the melting phase of EAF operation. All the VE readings for the fabric filter showed 0 percent opacity. The VE data is summarized in Table C-3.

C.1.1.11 Plant K. Plant K operates two EAF's, each rated at a 117.9-Mg (130-ton) capacity.[20] The heats are typically 4 to 5 hours in duration. The furnaces are on a staggered schedule. The emissions generated during meltdown and refining are captured by lateral (side) draft hoods. Above each furnace are two adjacent canopy hoods, one designed to capture charging emissions and the other designed to capture tapping emissions. Each hood has electrically controlled dampers to direct the flow to capture the emissions from the different furnace operations. There is a scavenger duct at this facility to capture any emissions that escape the canopy hood. The shop roof at Plant K is closed. The captured emissions are cleaned by a positive-pressure fabric filter rated at 424.7 m^3/s (900,000 acfm). The polyester filter bags can withstand a maximum temperature of 135°C (275°F) and the unit has an air-to-cloth ratio of 2.93:1.[21] The fabric filter exhausts through a continuous ridge ventilator. The fabric filter bags are cleaned by reverse air.

The emission test at Plant K was conducted with hi-vol samplers, and, therefore, the particulate emission data are not presented. Visible emission data were obtained from the fabric filter outlet and melt shop roof during the particulate matter emission sampling test. There were no visible emissions observed from the melt shop roof (600 minutes of observation) or the fabric filter outlet (300 minutes of observation) during the entire test period. These data are summarized in Table C-3.

C.1.1.12 Plant L. Plant L operates one EAF rated at a 90.7-Mg (100-ton) capacity with an average heat time of 2.25 hours. The furnace process emissions are captured by a DEC system while the fugitive emissions are captured by an overhead canopy hood. The DEC and canopy hood are ducted to a positive-pressure fabric filter that is cleaned by reverse air. The fabric filter has a design flow rate of 198.2 m^3/s (420,000 acfm) and a gross air-to-cloth ratio of 2.8:1. The pressure drop across the polyester bags is 1.74 to 2.24 kPa (7 to 9 in. w.g.).[22,23] The shop roof at this plant is closed; however, there was a continuous opening along the eaves of the roof and an open door on the shop wall that permitted the fugitive emissions that bypassed the canopy hood to escape the melt shop. For these two reasons, the VE data obtained at Plant L will not be used in support of a standard.

C.1.1.13 Plant M. Plant M operates four EAF's, two of which (Nos. 1 and 2) are older and have a melting capacity of 182 Mg (200 tons) each. The two newer furnaces (Nos. 3 and 4) have a melting capacity of 204.1 Mg (225 tons) each.[24] The process emissions from furnaces 1 and 2 are controlled by a wet scrubber, and the furnace fugitive emissions are uncontrolled. The emissions from each of the two newer furnaces (Nos. 3 and 4) are captured by a DEC system and canopy hood. At Plant M the shop roof is closed over the furnaces and the roof monitor is open elsewhere. The DEC systems and canopy hoods are ducted in common to a single positive-pressure fabric filter. The flow through the fabric filter is 825.8 m^3/s (1,750,000 acfm). The bags are cleaned by a mechanical shaker, and the gross air-to-cloth ratio is 3.4:1.[24,25] The pressure drop across the bags is 0.75 to 1.25 kPa (3 to 5 in. w.g.).[24,25]

The plant was visited to discuss the potential heat stress problem in warm and humid Southern locations. During the visit, a DEC malfunction allowed fugitive VE's to escape out the melt shop roof. In addition, two compartments in the baghouse were off-line for maintenance, and only three of the four fans were operating. For these reasons, the VE data obtained at Plant M will not be used to support a standard.

C.1.1.14 Plant N. Plant N operates two UHP EAF's. Furnace A has a melting capacity of 104 Mg (115 tons) and Furnace B has a melting capacity of 136 Mg (150 tons).[26] The process emissions from melting and refining are captured by separate DEC systems for each furnace. The fugitive emissions are captured by two canopy hoods located above Furnace A and one large canopy hood above Furnace B. There are sheet metal partitions suspended from the melt shop roof down to the crane level that create secondary collection zones to capture fugitive emissions not captured by the canopy hoods. These secondary collection zones are evacuated by scavenger ducts. The process and fugitive emission capture systems are ducted separately to a mixing chamber and then to the fabric filter control systems. The emissions from the furnaces are controlled by a positive-pressure fabric filter with a design flow rate of 212.4 m^3/s (450,000 acfm), a net air-to-cloth ratio of 3:1, and a pressure drop across each compartment of 2.0-2.5 kPa (8-10 in.) water and by a negative-pressure fabric filter with a design flow rate of 354 m^3/s (750,000 acfm), a net air-to-cloth ratio of 5.5:1 and a pressure drop of 1.75-2.0 kPa (7-8 in.) water.[26,27,28]

The first visit to this plant, in March 1981, was to review potential heat stress problems at plants in Southern locations. At the time of the visit, the plant was undergoing changes to accommodate the installation of a new furnace (Furnace B). A large opening in the side wall of the melt shop created cross-drafts within the shop that prevented effective capture of the charging and tapping emissions by the canopy hood. Thus, the VE data obtained at Plant N during the first visit will not be used to support a standard.[27]

The second visit to this plant, in August 1982, was to conduct a VE test on the melt shop roof monitor. All plant modifications to accommodate Furnace B, in process during the first visit, had been completed. This visit coincided with a compliance test performed on the control system associated with Furnace B (Furnace A was not operating due to reduced demand for Plant N products). Visible emission data were obtained from the melt shop roof monitor over Furnace B for 5.4 hours the first day and 8.4 hours the second day. On the first day, the maximum 6-minute average VE readings during charging, melting, and tapping were 3.3, 0, and 0 percent, respectively; and on the second day, the maximum readings were 3.3, 3.1, and 1.0 percent, respectively. Observations in the melt shop showed that these maximum opacity levels were achieved even during furnace upset conditions when melting emissions were not captured by the DEC system but were emitted into the shop and captured by the canopy hood and scavenger ducts. Melt shop observations showed that the uncontrolled emissions from the nitrogen stirring station combined with the emissions from the first charge of most heats. Table C-3 summarizes the VE data recorded during this visit.

C.1.1.15 Plant O. Plant O operates two EAF's, each with a rated capacity of 90.7 Mg (100 tons). (There is one additional 45.4-Mg [50-ton] furnace in the shop, but it has not been used in over 7 years.) The process emissions from each furnace are captured by a DEC system, while the fugitive emissions are captured by a segmented canopy hood. The shop roof monitor at Plant O is equipped with louvers that are designed to contain the emissions within the shop for capture by the canopy hood. When the louvers are opened, they vent heat and any emissions not captured by the canopy hood to the atmosphere.

Emissions captured by the DEC systems and canopy hoods are ducted in common to a single positive-pressure fabric filter with a design flow rate of 247.7 m^3/s (525,000 acfm). The fabric filter is cleaned by reverse air, and the net air-to-cloth ratio is 1.95:1.[29] The pressure drop across the bags is maintained between 0.75 and 1.75 kPa (3 and 7 in. w.g.).[29]

Plant O was visited to discuss the potential heat stress problems in warm climates and to observe the operation of a louvered roof monitor. The plant and the control system are old and underdesigned for capture of the fugitive emissions. Furthermore, the fabric filter was in need of maintenance during the visit. Several broken bags in some of the baghouse compartments allowed uncontrolled emissions to be vented to the atmosphere. For these reasons, the VE data obtained at the plant will not be used to support a standard.

C.2 EMISSION TEST DATA FOR FABRIC FILTERS ON ELECTRIC ARC FURNACES AND ARGON-OXYGEN DECARBURIZATION VESSELS IN THE SPECIALTY STEEL INDUSTRY

C.2.1. Particulate Matter and Visible Emissions

This section provides a summary of emission source test data on fabric filters installed at four specialty steel shops. The data includes fabric filters controlling EAF's alone, AOD vessels alone, and EAF and AOD vessels ducted together to a fabric filter. The particulate matter emissions at Plants P, Q, and R were measured by a Reference Method 5 sampling train and a summary of the data is presented in Figure C-2. The particulate matter

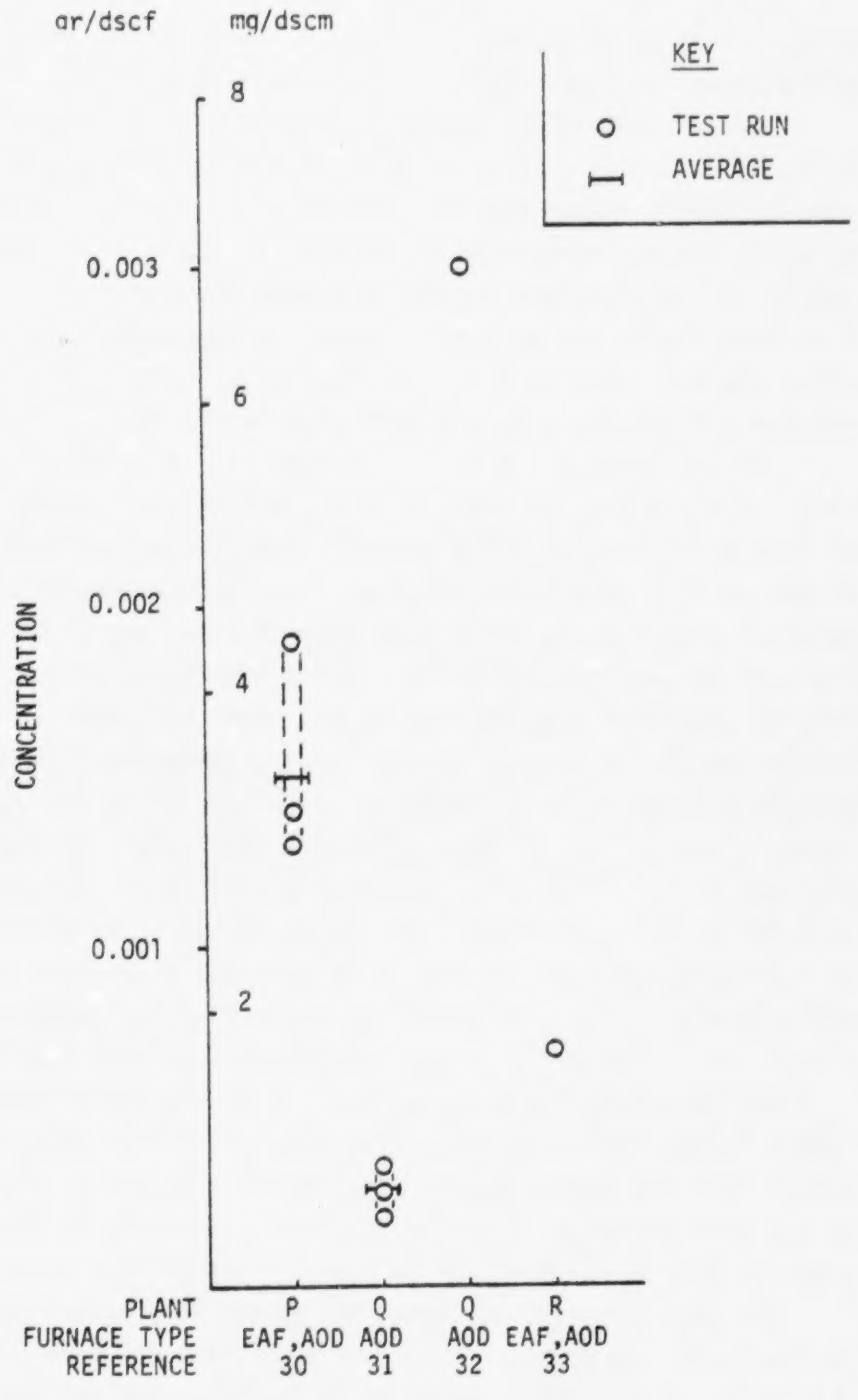

Figure C-2. Summary of particulate matter source test data for specialty steel shop fabric filters.

emission data for five additional plants were obtained using the hi-vol test method; however, these data are not presented here.

Opacity readings of the shop roof monitor exhaust gases were obtained at Plants P, Q, and S using EPA Reference Method 9. Opacity readings from the fabric filter monovent exhaust gas stream were taken at Plants P, Q, and S, and are summarized in Table C-14. Table C-15 presents a summary of the shop roof opacity data from Plants Q and S. Opacity data from Plant P will not be used to support standards because it is an older shop with open seams in the sheet metal section of the shop walls and does not represent best demonstrated technology.

C.2.1.1 Plant P. Plant P is a specialty steel mill that has two EAF's, each rated at 29.0 Mg (32 tons), and two AOD vessels, each rated at 29.0 Mg (32 tons).[30] The two EAF's feed the molten steel to either of the two AOD vessels for refining. The capture system for the EAF's consists of two canopy hoods above each furnace, one to capture charging and melting emissions and one to capture tapping emissions. Each canopy hood has automatic dampers that can be closed to direct more suction to another hood. The dampers on the charging canopy hood are always open whereas the dampers on the tapping side only open during the tap. Two canopy hoods are also located above each AOD vessel. These hoods are situated so that each canopy captures half of the refining emissions. Both AOD vessels have venturi-type diverter stacks to direct the emissions to the canopy hoods and to reduce the emission dispersion in the shop due to cross-drafts. The damper on each AOD vessel canopy hood is always open. The roof is closed over the entire melt shop at Plant P.

All the canopy hoods are ducted to the same positive-pressure fabric filter that has a rated flow rate of 282 m^3/s (600,000 acfm). The fabric filter is equipped with polyester bags that are cleaned automatically by a shaker mechanism. The gross air-to-cloth ratio is 2.65:1. The pressure drop across the bags is 1 to 1.5 kPa (4 to 6 in. w.g.).[34]

The fabric filter was tested for particulate matter concentrations at the inlet (two ducts) and the outlet. The tests were run to cover two full heats on one of the EAF's, while the other EAF and the two AOD vessels operated normally. Generally, the EAF's operate on a staggered schedule, and the average heat time (tap-to-tap) is 3.7 hours. The emission control system appeared to be operating normally during the test period.

Detailed results of the tests are presented in Tables C-16, C-17, and C-18. The particulate matter emission concentration for the north fabric filter inlet averaged 308 mg/dscm (0.134 gr/dscf) while the particulate matter concentration for south fabric filter inlet averaged 183 mg/dscm (0.080 gr/dscf). The outlet particulate matter concentrations determined for three samples were 3.27, 2.89, and 4.24 mg/ dscm, averaging 3.47 mg/dscm (0.00143, 0.00126, and 0.00185 gr/dscf, averaging 0.00151 gr/dscf).[30]

Concurrent with the fabric filter sampling, visible emission readings were obtained from the fabric filter and the roof monitor above the shop. This is an older shop with numerous holes in the closed roof and in the walls of the melt shop through which the fugitive emissions escaped. Visible emission readings on the fabric filter were taken for a total of 438 minutes with the maximum 6-minute average of 0 percent. In addition to the VE readings of the fabric filter and melt shop roof using Reference Method 9, the fabric filter dust-handling system was observed for fugitive emissions by Reference Method 22.

C.2.1.2 Plant Q. Plant Q operates five EAF's and two AOD vessels. Each of the EAF's has an average heat size of 13.6 Mg (15 tons). One of the AOD vessels has a 13.6-Mg (15-ton) capacity and the other has an 18.1-Mg (20-ton) capacity.[35] One emission test was conducted on the positive-pressure fabric filter associated with the 18.1-Mg (20-ton) AOD vessel.[32] The AOD vessel emissions are directed to a canopy hood by a movable diverter stack. The canopy hood is located above the crane in the roof trusses. The emissions that escape the canopy hood are withdrawn by a scavenger duct that is located at the high point of the closed roof. (In addition, a small amount of the fabric filter flow capacity is used to control cutting torch emissions at the continuous caster.) The total flow rate capacity of this fabric filter is 141.6 m^3/s (300,000 acfm).[35] The cleaned gases from the fabric filter are exhausted to the atmosphere via five stub stacks. Each stack exhausts cleaned gases from two compartments. The fabric filter is equipped with Dacron® bags and has a gross air-to-cloth ratio of 2.68:1.[35] The dirty bags are cleaned by reverse air. The pressure drop across the bags is 0.6 to 1.5 kPa (2.5 to 6 in. w.g.).

Simultaneous inlet and outlet tests for particulate matter were run on the fabric filter. The AOD vessel was operating at design capacity during the test, and the fabric filter appeared to be operating normally. The actual sampling time for each of the three test runs was 450 minutes. The average heat time was 1.6 hours, and these test runs included five to six heats per sampling period. The inlet particulate matter concentrations determined from the three tests were 150, 141, and 211 mg/dscm, averaging 167 mg/dscm (0.0655, 0.0617, and 0.0921 gr/dscfm, averaging 0.0731 gr/dscfm). Results of the inlet tests are presented in Table C-19. The outlet particulate matter concentrations determined from the three tests were 0.836, 0.497, and 0.650 mg/dscm, with an average of 0.661 mg/dscm (0.000365, 0.000217, and 0.000284 gr/dscf, with an average of 0.000289 gr/dscf).[31] The results of the outlet tests are presented in Table C-20.

Concurrent with the particulate matter sampling of the 18.1-Mg (20-ton) AOD vessel, visible emission readings were obtained from the shop roof and fabric filter outlets. No visible emissions were seen from either the shop roof or fabric filter during the test period (408 minutes of observation). In addition to these readings, fugitive emissions observations of the fabric filter dust-handling system were performed in accordance with Reference Methods 9 and 22.

Another Method 5 test was performed at this facility with only one sample run. A detailed description of this test is presented in Table C-21. The results of this test showed a particulate matter concentration of 6.87 mg/dscm (0.003 gr/dscf).[35]

C.2.1.3 Plant R. Plant R has two 38.1-Mg (42-ton) EAF's that operate on a staggered schedule to supply molten steel to one 45.4-Mg (50-ton) AOD vessel.[33] The emissions from both the EAF's and the AOD vessel are captured by overhead canopy hoods. Scavenger duct openings are utilized to capture fugitive emissions that escape the canopy hood. The emissions are cleaned by a positive-pressure fabric filter with a flow rate of 316 m^3/s (675,000 acfm).[33] The gross air-to-cloth ratio is 3.26:1. The 12-compartment fabric filter is equipped with polyester bags that are cleaned by reverse air. The fabric filter exhaust is vented out of one of two continuous ridge ventilators. The pressure drop across the bags is 1.5 to 2.0 kPa (6 to 8 in. w.g.).

Both the inlet and outlet of the fabric filter were tested for particulate matter concentration. The inlet was sampled with a standard Reference Method 5 probe and sampling train, and the average of the two inlet tests was 178.7 mg/dscm (0.07804 gr/dscf).[33] A detailed summary of the inlet test is presented in Table C-22. The outlets of 3 of the 12 compartments were sampled for 2-1/2 hours by traversing the top of each compartment with a nozzle filter assembly of the Reference Method 5 sampling train. The outlet particulate matter concentration varied from 0.413 to 3.94 mg/dscm (0.00018 to 0.00172 gr/dscf).[33] The detailed summary of this test is presented in Table C-23.

C.2.1.4 Plant S. Plant S operates one 45.4-Mg (50-ton) EAF and one 45.4-Mg (50-ton) AOD vessel.[37] The emissions from the EAF and AOD vessel are controlled by two fabric filters. The EAF emissions are captured by an overhead canopy hood and ducted to a negative-pressure fabric filter. Fugitive emissions from the AOD vessel are eventually controlled by this fabric filter since the shop roof is closed and the AOD emissions drift to the EAF canopy hood. The negative-pressure fabric filter has a design flow rate of 108.5 m^3/s (230,000 acfm) and utilizes Dacron® bags with an air-to-cloth ratio of 3.62:1. The bags are cleaned by a shaker mechanism. This fabric filter exhausts the cleaned gases out a large steel stack.[37] The pressure drop across the fabric filter bags is 1.25 to 2.50 kPa (5 to 10 in. w.g.).

The primary exhaust from the AOD vessel is captured by a bell-shaped hood immediately above the vessel mouth. The primary emissions are ducted along with the teeming aisle fumes and some of the EAF fumes to a positive-pressure fabric filter. This fabric filter has a design flow rate of 108.5 m^3/s (230,000 acfm) and utilizes Dacron® bags with an air-to-cloth ratio of 3:62:1.[37] The bags are cleaned by reverse air. This fabric filter exhausts the cleaned gases through a continuous ridge ventilator.

Visible emission readings were taken at this plant at both fabric filters and at the shop roof above both the EAF and AOD vessel.[38] A total of 61 six-minute sets of visible emission readings were recorded for the melt shop roof, 56 sets for the EAF fabric filter stack, and 53 sets for the AOD fabric filter roof monitor. All sets averaged 0 percent opacity except for two sets taken at the melt shop roof during the EAF melting and AOD refining phases. These two 6-minute average were 1 and 5 percent, respectively.

C.3 VISIBLE EMISSION DATA FOR DUST-HANDLING SYSTEMS FOR BOTH CARBON AND SPECIALTY STEEL PLANTS

Visible emission data were obtained from the dust-handling systems at four steel mills. As mentioned in Chapter 4, the dust-handling equipment includes the baghouse dust hoppers, the pneumatic system that conveys the dust to the storage bin, the storage bin, and the dust transfering system that conveys the dust from the storage bin to a truck. Table C-24 summarizes the results from Plants B and C, carbon steel plants, and Plants P and Q, specialty steel plants. The highest recorded opacity for 734 minutes of readings with both Reference Methods 9 and 22 was a 6-minute average of 7.3 percent. This high opacity observation was made during a storage-bin-to-truck transfer operation.

C.4 ENGLISH/METRIC CONVERSIONS

The information in the test reports was furnished in English units. The following shows the conversion factors used to report the data in metric units. The factors were taken from "Standard for Metric Practice," American Society for Testing and Materials, September 1977.

English units	Multiply by	Metric unit
inches, Hg	3,376.85	pascals
inches, H_2O	248.84	pascals
cubic feet	0.0283	cubic meters

English units	Multiply by	Metric unit
gr/dscf	2,290	mg/dscm
foot	0.3048	meters
grains	0.0648	grams

TABLE C-1. SUMMARY OF PLANTS TESTED AND TYPE OF TESTS PERFORMED

Plant	Product grade	No. of furnaces	Furnace/ vessel	Furnace size Mg	Furnace size tons	Type of test performed
A	Carbon steel	2	EAF	45.4, 68	50, 75	Method 5
B	Carbon steel	2	EAF	36.3, 22.7	40, 25	Method 5, 9
C	Carbon steel	1	EAF	49.9	55	Method 5, 9
D	Carbon steel	1	UHP EAF	108.8	120	Method 5
E	Carbon steel	1	EAF	117.9	130	Method 5
F	Carbon steel	3	EAF	45.4	50	Method 5, 9
G	Carbon steel	1	EAF	108.9	120	Method 5, 9
H	Carbon steel	2	EAF	90.7	100	Method 5, 9
I	Carbon steel	2	EAF	108.9	120	Method 9
J	Carbon steel	2	UHP EAF	317.5	350	Method 9
K	Carbon steel	1	EAF	117.9	130	Method 9
L	Carbon steel	3	EAF	90.7	100	Method 9
M	Carbon steel	2	EAF	204.1	225	Method 9
N	Carbon steel	2	UHP EAF	136, 104	150, 115	Method 9
O	Carbon steel	2	EAF	90.7	100	Method 9
P	Specialty steel	2 2	EAF AOD	29.0 29.0	32 32	Method 5, 9, 22 Method 5, 9, 22
Q	Specialty steel	1	AOD	18.1	20	Method 5, 9
R	Specialty steel	2 1	EAF AOD	38.1 45.4	42 50	Method 5
S	Specialty steel	1 1	EAF AOD	45.4 45.4	50 50	Method 9 Method 9

TABLE C-2. SUMMARY OF VISIBLE EMISSION DATA FROM FABRIC FILTERS ON EAF'S AT CARBON STEEL SHOPS[5,7-10,16,18,20]

Plant	Length of observation, minutes	Maximum 6-minute average opacity, percent
B[a]	960	2.5[b]
C[a]	596[c]	0
F[a]	18	0
G[d]	936	2.8[b]
H[d]	120	0
I[d]	60	0
J[d]	577	0[e]
K[c]	300	0

[a] Single stack exhaust.

[b] Not 6-minute average; average from continuous monitor during Reference Method 5 test.

[c] Combination of data from two tests.

[d] Monovent exhaust.

[e] EPA Method 22.

TABLE C-3. SUMMARY OF OPACITY DATA FROM SHOP ROOF MONITORS AT CARBON STEEL SHOPS[5,9,10,16,19,20,26]

Plant	Furnace	Furnace process	No. of 6-minute averages	Maximum 6-minute average opacity, percent	Average 6-minute average opacity, percent
C[a]	EAF	Charge	5	1.3	0.5
		Melt	33	2.7	0.1
		Tap	6	0.4	0.1
C[a]	EAF	Heat cycle	88	5.0	0.25
G[b]	EAF	Heat cycle	46	0	0
H[c]	EAF	Charge	10	12	5.0
		Melt	95	0	0
		Tap	5	33	23.0
I[b]	EAF	Heat cycle	10	0	0
J[d]	EAF	Charge	15	4.4	1.0
		Melt	106	4.2	0.2
		Tap	10	5.0	0.6
K[e]	EAF	Charge	5	0	0
		Melt	90	0	0
		Tap	5	0	0
N[f]	EAF	Charge	30	3.3	0.7
		Melt	94	3.1	0.1
		Tap	14	1.0	0.1

[a] Utilizes total furnace enclosure, canopy hood, closed roof.

[b] Utilizes canopy hood, DEC, closed roof.

[c] Utilizes canopy hood, DEC, open roof.

[d] Utilizes canopy hood, DEC, local tapping hood, closed roof over furnaces/open elsewhere.

[e] Utilizes canopy hood, side draft hood, tapping hood, closed roof.

[f] Utilizes canopy hood, DEC, scavenger ducts with cross-draft partitions, closed roof over furnace/open elsewhere.

TABLE C-4. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT A[1] (Fabric filter inlet)[a]

	Units	Run number/date 1 10/18/72	 2 10/19/72	 3 10/20/72	Average
Test data					
Sampling time	min	240	240	240	240
Furnace production	Mg/h	--	--	--	--
	tons/h	--	--	--	--
Nominal furnace capacity	Mg	113.4	113.4	113.4	113.4
	tons	125	125	125	125
Shop effluent					
Flow rate	m^3/min	13,349	14,066	14,283	13,899
	acfm	471,699	497,016	504,697	491,137
	dscm/min	12,204	12,875	13,309	12,796
	dscfm	431,236	454,932	470,300	452,156
Flow rate per unit of furnace capacity	dscm/min/Mg	--	--	--	--
	dscfm/ton	--	--	--	--
Temperature	°C	37	38	34.9	36.6
	°F	98.6	100.4	94.8	97.9
Water vapor	% volume	0.7	0.6	0.6	0.6
CO_2 dry	% volume	<0.1	<0.1	<0.1	<0.1
O_2 dry	% volume	20.6	20.2	20.7	20.5
Particulate matter emissions					
Mass collected	mg	437.9	666.1	732.5	612
	gr	6.76	10.28	11.30	9.45
Concentration	mg/dscm	80.84	118.2	129.2	109.4
	gr/dscf	0.0353	0.0516	0.0564	0.0478
Emission rate	kg/h	64.9	99.8	110.7	91.8
	lb/h	143	220	244	202
Emission factor	kg/Mg	--	--	--	--
	lb/ton	--	--	--	--

[a] Reference Method 5 data.

TABLE C-5. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT A[1]
(Fabric filter outlet)[a]

		Run number/date			
	Units	1 10/18/72	2 10/19/72	3 10/20/72	Average
Test data					
Sampling time	min	240	240	240	240
Furnace production	Mg/h	--	--	--	--
	tons/h	--	--	--	--
Nominal furnace capacity	Mg	113.4	113.4	113.4	113.4
	tons	125	125	125	125
Shop effluent					
Flow rate[b]	m^3/min	6,480	6,353	6,526	6,453
	acfm	228,978	224,479	230,592	228,016
	dscm/min	5,924	5,842	6,008	5,925
	dscfm	209,343	206,431	212,283	209,352
Flow rate per unit of furnace capacity	dscm/min/Mg	--	--	--	--
	dscfm/ton	--	--	--	--
Temperature[b]	°C	38.9	38.3	37.5	38.2
	°F	102	101	99.5	100.8
Water vapor[b]	% volume	0.6	0.5	0.5	0.5
CO_2 dry	% volume	<0.1	<0.1	<0.1	<0.1
O_2 dry	% volume	20.6	20.2	20.7	20.5
Particulate matter emissions[b]					
Mass collected	mg	74.6	35.3	36.3	48.7
	gr	1.15	0.54	0.56	0.75
Dust concentration	mg/dscm	4.81	2.22	2.29	3.11
	gr/dscf	0.0021	0.00097	0.001	0.0014
Emission rate	kg/h	5.9	3.4	4.8	4.7
	lb/h	12.9	7.41	10.5	10.3
Emission factor	kg/Mg	--	--	--	--
	lb/ton	--	--	--	--

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[a] Reference Test Method 5 data. Baghouse has six 9-ft-diameter stacks. Three stacks sampled simultaneously. Emission rate based on inlet gas flow.

[b] Total through three of six stacks.

TABLE C-6. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT B[3]
(Fabric filter outlet--Canopy hood)[a]

		Run number/date			
		1	2	3	
	Units	01/22/80	01/22/80	01/23/80	Average
Test data					
Sampling time	min	240	240	240	240
Furnace production	Mg/h	13.8	22.6	15.5	17.3
	tons/h	15.2	24.9	17.1	19.1
Nominal furnace capacity	Mg	36.3	36.3	36.3	36.3
	tons	40	40	40	40
Shop effluent					
Flow rate	m^3/min	2,580	2,496	2,447	2,508
	acfm	91,183	88,190	86,454	88,942
	dscm/min	2,377	2,328	2,279	2,328
	dscfm	83,977	82,270	80,516	82,254
Flow rate per unit of furnace capacity	dscm/min/Mg	65.5	64.1	62.8	64.1
	dscfm/ton	2,099	2,057	2,013	2,056
Temperature	°C	25	22.2	22.8	23.3
	°F	77	72	73	74
Water vapor	% volume	1.2	0.8	0.8	0.9
CO_2 dry	% volume	0	0	0	0
O_2 dry	% volume	20.9	20.9	20.9	20.9
Particulate matter emissions					
Concentration	mg/m^3	1.37	1.15	3.89	2.14
	gr/acf	0.0006	0.0005	0.0017	0.0009
	mg/dscm	1.60	1.15	4.12	2.29
	gr/dscf	0.0007	0.0005	0.0018	0.001
Emission rate	kg/h	0.22	0.17	0.55	0.31
	lb/h	0.49	0.38	1.21	0.69
Emission factor	kg/Mg	0.016	0.008	0.035	0.02
	lb/ton	0.032	0.015	0.071	0.039

[a] Reference Method 5 data.

TABLE C-7. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT B[4] (Fabric filter outlet--Side draft hood)[a]

		Run number/date			
	Units	1 05/05/80	2 05/06/80	3 05/06/80	Average
Test data					
Sampling time	min	240	240	240	240
Furnace production	Mg/h	--	--	--	--
	tons/h	--	--	--	--
Nominal furnace capacity	Mg	36.3	36.3	36.3	36.3
	tons	40	40	40	40
Shop effluent					
Flow rate	m^3/min	3,563	3,615	3,722	3,633
	acfm	125,900	127,741	131,527	128,389
	dscm/min	2,972	3,048	3,090	3,037
	dscfm	105,032	107,712	109,200	107,315
Flow rate per unit of furnace capacity	dscm/min/Mg	81.9	84.0	85.1	83.7
	dscfm/ton	2,625.8	2,693	2,730	2,683
Temperature	°C	66	63	67.6	65.5
	°F	150.9	138.8	149	146.2
Water vapor	% volume	0.008	0.013	0.012	0.011
CO_2 dry	% volume	0	0	0	0
O_2 dry	% volume	--	--	--	--
Particulate matter emissions					
Concentration	mg/m^3	5.5	5.27	3.89	4.89
	gr/acf	0.0024	0.0023	0.0017	0.0021
	mg/dscm	6.41	6.64	4.81	5.95
	gr/dscf	0.0028	0.0029	0.0021	0.0026
Emission rate	kg/h	1.16	1.18	0.88	1.07
	lb/h	2.56	2.61	1.93	2.37
Emission factor	kg/Mg	--	--	--	--
	lb/ton	--	--	--	--

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[a] Reference Method 5 data.

TABLE C-8. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT C[5] (Fabric filter outlet)[a]

		Run number/date			
	Units	1	2	3	Average
Test data					
Sampling time	min	333	179	182	231.3
Furnace production	Mg/h	18.85	16.46	17.48	17.60
	tons/h	20.78	18.14	19.27	19.40
Nominal furnace capacity	Mg	49.9	49.9	49.9	49.9
	tons	55	55	55	55
Shop effluent					
Flow rate	m^3/min	3,609	3,674	3,580	3,621
	acfm	127,527	129,830	126,487	127,948
	dscm/min	3,279	3,341	3,316	3,312
	dscfm	115,867	118,062	117,179	117,036
Flow rate per unit of furnace capacity	dscm/min/Mg	65.7	70.0	66.5	66.4
	dscfm/ton	2,107	2,147	2,131	2,128
Temperature	°C	63.1	62.6	56.3	60.7
	°F	145.5	144.6	133.4	141.2
Water vapor	% volume	0.26	0.36	0.03	0.22
CO dry	% volume	--	--	--	--
O_2 dry	% volume	--	--	--	--
CO_2 dry	% volume	--	--	--	--
Particulate matter emissions					
Concentration	mg/m^3	2.98	2.47	2.70	2.72
	gr/acf	0.00130	0.00108	0.00118	0.00119
	m/dscm	3.05	2.52	2.79	2.79
	gr/dscf	0.00133	0.00110	0.00122	0.00122
Emission rate	kg/h	0.60	0.51	0.56	0.56
	lb/h	1.324	1.121	1.227	1.224
Emission factor	kg/Mg	0.032	0.031	0.032	0.032
	lb/ton	0.064	0.062	0.064	0.063

[a] Reference Method 5 data.

TABLE C-9. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT D[6] (Fabric filter outlet)[a]

		Run number/date			
	Units	1 12/18/80	2 12/19/80	3 12/19/80	Average
Test data					
Sampling time	min	96	96	96	96
Furnace production	Mg/h	63.9	58.4	58.8	60.4
	tons/h	70.4	64.4	64.8	66.5
Nominal furnace capacity	Mg	108.8	108.8	108.8	108.8
	tons	120	120	120	120
Shop effluent					
Flow rate	m^3/min	9,520	9,848	10,089	9,819
	acfm	336,400	348,000	356,500	347,000
	dscm/min	8,765	9,265	9,667	9,232
	dscfm	309,700	327,400	341,600	326,200
Flow rate per unit of furnace capacity	dscm/min/Mg	80.6	85.2	88.9	84.9
	dscfm/ton	2,581	2,728	2,847	2,719
Temperature	°C	35.3	34.6	29.4	33.1
	°F	95.5	94.3	85	91.6
Water vapor	% volume	0.80	0.71	0.70	0.74
CO_2 dry	% volume	0.1	<0.1	<0.1	<0.1
O_2 dry	% volume	21.0	21.0	21.0	21.0
Particulate matter emissions					
Concentration	mg/m^3	1.75	3.60	1.91	2.42
	gr/acf	0.00076	0.00157	0.00083	0.00105
	mg/dscm	1.9	3.82	1.99	2.57
	gr/dscf	0.00083	0.00167	0.00087	0.0011
Emission rate	kg/h	1.0	2.1	1.1	1.4
	lb/h	2.2	4.7	2.5	3.13
Emission factor	kg/Mg	0.016	0.036	0.019	0.024
	lb/ton	0.031	0.073	0.039	0.048

[a] Reference Method 5 data.

TABLE C-10. SUMMARY OF PARTICULATE MATTER RESULTS[a]--PLANT E[7]
(Fabric filter outlet)

		Run number/date			
	Units	1 06/12/80	2 06/13/80	3 06/13/80	Average
Test data					
Sampling time	min	240	240	240	240
Furnace production	Mg/h	35.2	62.8	37.2	45.1
	tons/h	38.8	69.2	41.0	49.7
Nominal furnace capacity	Mg	117.9	117.9	117.9	117.9
	tons	130	130	130	130
Shop effluent					
Flow rate	m^3/min	15,448	15,390	15,360	15,400
	acfm	545,875	543,800	542,765	544,150
	dscm/min	13,267	13,186	13,258	13,237
	dscfm	468,785	475,936	468,494	471,070
Flow rate per unit of furnace capacity	dscm/min/Mg	112.5	111.8	112.5	112.3
	dscfm/ton	3,606	3,661	3,604	3,624
Temperature	°C	68.3	67.8	66.1	67.4
	°F	155	154	151	153.3
Water vapor	% volume	1.5	1.8	1.5	1.6
CO_2 dry	% volume	0.1	0.1	0.1	0.1
O_2 dry	% volume	19.3	17.1	18.3	18.2
Particulate matter emissions					
Concentration	mg/m^3	2.98	2.98	3.66	3.21
	gr/acf	0.0013	0.0013	0.0016	0.0014
	mg/dscm	3.44	3.44	4.12	3.67
	gr/dscf	0.0015	0.0015	0.0018	0.0016
Emission rate	kg/h	2.7	2.7	3.3	2.9
	lb/h	5.9	5.9	7.2	6.3
Emission factor	kg/Mg	0.08	0.04	0.09	0.07
	lb/ton	0.15	0.09	0.18	0.14

[a] Reference Method 5 data.

TABLE C-11. SUMMARY OF PARTICULATE MATTER RESULTS[a]--PLANT F[8]
(Fabric filter outlet)

	Units	Run number/date 1 11/17/81	2 11/17/81	3 11/18/81	Average
Test data					
Sampling time	min	288	288	288	288
Furnace production	Mg/h	67.7	67.7	63.3	66.2
	tons/h	74.6	74.6	69.8	73.0
Nominal furnace capacity	Mg	136.1	136.1	136.1	136.1
	tons	150	150	150	150
Shop effluent					
Flow rate	m^3/min	19,901	20,256	19,651	19,936
	acfm	702,878	715,400	694,022	704,100
	dscm/min	17,638	17,957	17,083	17,559
	dscfm	622,750	635,750	603,200	620,567
Flow rate per unit of furnace capacity	dscm/min/Mg	129.6	131.9	125.5	129.0
	dscfm/ton	4,152	4,238	4,021	4,137
Temperature	°C	47.2	46.7	51.1	48.3
	°F	117	116	124	119
Water vapor	% volume	1.6	1.6	1.8	1.7
CO_2 dry	% volume	--	--	--	--
O_2 dry	% volume	--	--	--	--
Particulate emissions					
Concentration	mg/m^3	1.62	2.23	1.59	1.81
	gr/acf	0.0007	0.0010	0.0007	0.0008
	mg/dscm	1.83	2.52	1.83	2.06
	gr/dscf	0.0008	0.0011	0.0008	0.0009
Emission rate	kg/h	1.94	2.71	1.88	2.18
	lb/h	4.27	5.98	4.14	4.80
Emission factor[a]	kg/Mg	0.03	0.04	0.03	0.033
	lb/ton	0.06	0.08	0.06	0.067

[a] Reference Method 5 data.

TABLE C-12. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT G[9]
(Fabric filter outlet)[a]

		Run number/date			
	Units	1 12/15/81	2 12/17/81	3 12/17/81	Average
Test data					
Sampling time	min	390	276	270	312
Furnace production	Mg/h	27.7	38.7	41.0	35.8
	tons/h	30.5	42.7	45.2	39.5
Nominal furnace capacity	Mg	108.9	108.9	108.9	108.9
	tons	120	120	120	120
Shop effluent					
Flow rate	m^3/min	11,404	9,347	9,567	10,109
	acfm	402,965	330,280	338,370	357,205
	dscm/min	10,953	8,832	8,913	9,566
	dscfm	387,030	312,086	314,943	338,020
Flow rate per unit of furnace capacity	dscm/min/Mg	100.6	81.1	81.8	87.8
	dscfm/ton	3,225	2,601	2,625	2,817
Temperature	°C	32.2	34.4	40.6	35.7
	°F	90	94	105	96.3
Water vapor	% volume	0.4	0.5	0	0.3
CO_2 dry	% volume	--	--	--	--
O_2 dry	% volume	--	--	--	--
Particulate emissions					
Concentration	mg/m^3	10.1	5.7	1.0	5.6
	gr/acf	0.0045	0.0024	0.0004	0.0024
	mg/dscm	10.5	5.90	1.1	5.9
	gr/dscf	0.0046	0.0026	0.0005	0.0026
Emission rate	kg/h	6.98	3.08	0.56	3.54
	lb/h	15.39	6.78	1.24	7.80
Emission factor[a]	kg/Mg	0.25	0.08	0.014	0.115
	lb/ton	0.50	0.16	0.03	0.23

[a] Reference Method 5 data.

TABLE C-13. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT H[10] (DEC fabric filter outlet)[a]

		Run number/date
	Units	1 08/28/73
Test data		
Sampling time	min	240
Furnace production	Mg/h	--
	tons/h	--
Nominal furnace capacity	Mg	99.8
	tons	110
Shop effluent		
Flow rate	m^3/min	4,379
	acfm	154,650
	dscm/min	3,675
	dscfm	129,800
Flow rate per unit of furnace capacity	dscm/min/Mg	36.8
	dscfm/ton	1,180
Temperature	°C	41.7
	°F	107
Water vapor	% volume	3.16
CO$_2$ dry	% volume	--
O$_2$ dry	% volume	--
Particulate emissions		
Concentration	mg/m^3	5.04
	gr/acf	0.0022
	mg/dscm	5.95
	gr/dscf	0.0026
Emission rate	kg/h	2.60
	lb/h	2.87
Emission factor[a]	kg/Mg	--
	lb/ton	--

[a] Modified Reference Method 5.

TABLE C-14. SUMMARY OF VISIBLE EMISSION DATA FROM FABRIC FILTERS AT SPECIALTY STEEL SHOPS[30,31,38]

Plant	Length of observations, minutes	Maximum 6-minute average opacity, percent
P	438[a]	0
Q	408[b]	0
S	336[c]	0
	318[b]	0

[a] One fabric filter for EAF and AOD vessels.
[b] AOD vessel fabric filter.
[c] EAF fabric filter.

TABLE C-15. SUMMARY OF VISIBLE EMISSION DATA FROM SHOP ROOF MONITORS ON SPECIALTY STEEL SHOPS[31,38]

Plant	Furnace/vessel	Furnace process	No. of 6-minute averages	Maximum 6-minute average opacity, percent
Q[a]	AOD	Heat cycle	69	0
S[b]	EAF and AOD	Heat cycle	55	5

[a] Utilizes diverter stack, canopy hood, scavenger duct, and closed roof.
[b] Utilizes close-fitting hood, canopy hood, and closed roof.

TABLE C-16. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT P30 (South fabric filter inlet)[a]

	Units	Run number/date 1 04/07/81	 2 04/08/81	 3 04/09/81	Average
Test data					
Sampling time	min	360	360	360	360
Furnace production	Mg/h	--	--	--	--
	tons/h	--	--	--	--
Nominal furnace capacity	Mg	--	--	--	--
	tons	--	--	--	--
Shop effluent					
Flow rate	m^3/min	8,442	8,466	8,634	8,514
	acfm	298,100	298,900	304,800	300,600
	dscm/min	7,794	7,758	7,824	7,792
	dscfm	275,200	273,900	276,300	275,100
Flow rate per unit of furnace capacity	dscm/min/Mg	--	--	--	--
	dscfm/ton	--	--	--	--
Temperature	°C	46.7	47.8	45.6	46.7
	°F	116	118	114	116
Water vapor	% volume	0.65	0.69	1.29	0.88
CO_2 dry	% volume	--	--	--	--
O_2 dry	% volume	--	--	--	--
Particulate matter emissions					
Concentration	mg/m^3	183	220	101	168
	gr/acf	0.080	0.096	0.044	0.073
	mg/dscm	198	240	111	183
	gr/dscf	0.0867	0.1047	0.0485	0.080
Emission rate	kg/h	93	111	52	86
	lb/h	205	246	115	188
Emission factor	kg/Mg	--	--	--	--
	lb/ton	--	--	--	--

[a] Reference Method 5 data.

TABLE C-17. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT P[30]
(North fabric filter inlet)[a]

		Run number/date			
	Units	1 04/07/81	2 04/08/81	3 04/09/81	Average
Test data					
Sampling time	min	360	360	360	360
Furnace production	Mg/h	--	--	--	--
	tons/h	--	--	--	--
Nominal furnace capacity	Mg	--	--	--	--
	tons	--	--	--	--
Shop effluent					
Flow rate	m^3/min	8,376	7,980	8,304	8,220
	acfm	295,800	281,900	293,300	290,300
	dscm/min	7,800	7,308	7,632	7,580
	dscfm	275,500	258,200	269,600	267,800
Flow rate per unit of furnace capacity	dscm/min/Mg	--	--	--	--
	dscfm/ton	--	--	--	--
Temperature	°C	43.3	47.2	41.7	44
	°F	110	117	107	111
Water vapor	% volume	0.81	0.89	1.25	0.98
CO_2 dry	% volume	--	--	--	--
O_2 dry	% volume	--	--	--	--
Particulate matter emissions					
Concentration	mg/m^3	202	166	482	283
	gr/acf	0.088	0.0727	0.2103	0.124
	mg/dscm	217	182	523	307
	gr/dscf	0.0948	0.0794	0.2288	0.1343
Emission rate	kg/h	102	80	240	141
	lb/h	224	176	529	310
Emission factor	kg/Mg	--	--	--	--
	lb/ton	--	--	--	--

[a] Reference Method 5 data.

TABLE C-18. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT P[30]
(Fabric filter outlet)[a]

		Run number/date			
	Units	1 04/07/81	2 04/08/81	3 04/09/81	Average
Test data					
Sampling time	min	330	330	330	330
Furnace production[b]	Mg/h	28.9	30.2	28.2	29.1
	tons/h	31.9	33.3	31.1	32.1
Nominal furnace capacity	Mg	116	116	116	116
	tons	128	128	128	128
Shop effluent					
Flow rate	m^3/min	16,542	16,380	16,920	16,614
	acfm	584,100	578,600	597,600	586,800
	dscm/min	15,594	15,066	15,456	15,372
	dscfm	550,700	532,100	545,900	542,900
Flow rate per unit of furnace capacity	dscm/min/Mg	134	130	133	132
	dscfm/ton	4,302	4,157	4,265	4,241
Temperature	°C	42	48	46	45.3
	°F	108	119	114	114
Water vapor	% volume	0.41	0.68	1.17	0.75
CO_2 dry	% volume	--	--	--	--
O_2 dry	% volume	--	--	--	--
Particulate matter emissions					
Concentration	mg/m^3	3.09	2.66	3.87	3.21
	gr/acf	0.00135	0.00116	0.00169	0.0014
	mg/dscm	3.27	2.88	4.24	3.46
	gr/dscf	0.00143	0.00126	0.00185	0.00151
Emission rate	kg/h	3.06	2.61	3.94	3.20
	lb/h	6.75	5.75	8.68	7.06
Emission factor	kg/Mg	0.11	0.09	0.14	0.11
	lb/ton	0.21	0.17	0.28	0.22

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[a] Reference Method 5 data.

[b] Basis: Three of four furnaces operating at the same time.

TABLE C-19. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT Q[31]
(Fabric filter inlet)[a]

		Run number/date			
	Units	1 04/28/81	2 04/29/81	3 04/30/81	Average
Test data					
Sampling time	min	450	450	450	450
Furnace production	Mg/h	9.5	8.6	9.3	9.1
	tons/h	10.5	9.5	10.3	10.1
Nominal vessel capacity	Mg	18.1	18.1	18.1	18.1
	tons	20	20	20	20
Shop effluent					
Flow rate	m^3/min	9,000	9,486	8,994	9,160
	acfm	317,800	335,000	317,600	323,500
	dscm/min	7,836	8,322	7,998	8,052
	dscfm	276,800	293,800	282,400	284,300
Flow rate per unit of furnace capacity	dscm/min/Mg	433	460	442	445
	dscfm/ton	13,840	14,690	14,120	14,215
Temperature	°C	57	51	50	53
	°F	135	124	122	127
Water vapor	% volume	1.1	1.7	0.9	1.2
CO_2 dry	% volume	0.6	0.6	0.6	0.6
O_2 dry	% volume	19.4	19.4	19.4	19.4
Particulate matter emissions					
Concentration	mg/m^3	131	124	188	148
	gr/acf	0.057	0.0541	0.0819	0.0643
	mg/dscm	150	141	211	167
	gr/dscf	0.0655	0.0617	0.0921	0.0731
Emission rate	kg/h	70.5	70.5	101.2	80.7
	lb/h	155.4	155.3	223.0	177.9
Emission factor	kg/Mg	7.4	8.2	10.9	8.8
	lb/ton	14.8	16.3	21.6	17.6

[a] Reference Method 5 data.

TABLE C-20. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT Q[31]
(Fabric filter outlet)[a]

		Run number/date			
	Units	1 04/28/81	2 04/29/81	3 04/30/81	Average
Test data					
Sampling time	min	480	480	480	480
Furnace production	Mg/h	9.5	8.6	9.3	9.1
	tons/h	10.5	9.5	10.3	10.1
Nominal furnace capacity	Mg	18.1	18.1	18.1	18.1
	tons	20	20	20	20
Shop effluent					
Flow rate	m^3/min	3,990	4,320	4,566	4,292
	acfm	141,000	152,800	161,300	151,700
	dscm/min	3,540	3,780	4,110	3,810
	dscfm	125,100	133,400	142,200	133,600
Flow rate per unit of furnace capacity	dscm/min/Mg	196	209	227	210
	dscfm/ton	6,255	6,670	7,110	6,680
Temperature	°C	55	55	49	53
	°F	130	131	119	127
Water vapor	% volume	0.3	0.3	0.5	0.37
CO_2 dry	% volume	0.6	0.6	0.6	0.6
O_2 dry	% volume	19.4	19.4	19.4	19.4
Particulate matter emissions					
Concentration	mg/m^3	0.742	0.433	0.573	0.583
	gr/acf	0.000324	0.000189	0.000250	0.000254
	mg/dscm	0.827	0.493	0.650	0.651
	gr/dscf	0.000365	0.000217	0.000284	0.000289
Emission rate	kg/h	0.390	0.246	0.312	0.316
	lb/h	0.859	0.542	0.687	0.696
Emission factor	kg/Mg	0.041	0.029	0.034	0.035
	lb/ton	0.082	0.057	0.067	0.069

[a] Reference Method 5 data.

TABLE C-21. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT Q[32]
(Fabric filter outlet)[a]

	Units	Run No. 1[b] 08/22/78
Test data		
Sampling time	min	240
Furnace production	Mg/h	11.6
	tons/h	12.8
Nominal furnace capacity	Mg	18.1
	tons	20
Shop effluent		
Flow rate	m^3/min	811
	acfm	28,655
	dscm/min	719
	dscfm	25,394
Flow rate per unit of furnace capacity	dscm/min/Mg	39.7
	dscfm/ton	1,270
Temperature	°C	57.2
	°F	135
Water vapor	% volume	0.016
CO_2 dry	% volume	--
O_2 dry	% volume	--
Particulate matter emissions		
Concentration	mg/m^3	6.18
	gr/acf	0.0027
	mg/dscm	6.87
	gr/dscf	0.003
Emission rate	kg/h	0.30
	lb/h	0.67
Emission factor	kg/Mg	0.026
	lb/ton	0.052

[a] Reference Method 5 data.
[b] This test involved only one run.

TABLE C-22. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT R[33]
(Fabric filter inlet)[a]

		Run number/date		
	Units	1 02/10/78	2 02/13/78	Average
Test data				
Sampling time	min	251	189	220
Gas velocity	m/s	25.09	25.88	25.48
Flow rate	dscm/min	17,717	17,880	17,798
	dscfm	626,038	631,804	628,921
Temperature	°C	35.4	40.3	37.9
	°F	95.7	104.6	100.2
Water vapor	% volume	0.0	0.5	0.25
CO_2 dry	% volume	1.6	1.1	1.4
O_2 dry	% volume	19.0	19.6	19.3
CO dry	% volume	0.0	0.0	0.0
Particulate matter emissions				
Concentration	mg/dscm	187.2	170.3	178.7
	gr/dscf	0.08174	0.07435	0.07804
Emission rate	kg/h	198.9	182.6	190.8
	lb/h	438.6	402.63	420.62

[a] Reference Method 5 data.

TABLE C-23. SUMMARY OF PARTICULATE MATTER RESULTS--PLANT R[33]
(Fabric filter outlet)[a]

		Run number/date									
		1	2	3	4	5	6	8	9	10	
		02/10/78	02/11/78	02/13/78	02/13/78	02/14/78	02/14/78	03/06/78	03/06/78	03/07/78	Average
		Compartment number									
	Units	2	2	2	8	8	8	11	11	11	
Sampling time	min	144	144	144	144	144	144	144	120	144	141.3
Furnace production	Mg/h	37.120	24.684	27.188	33.367	39.688	28.482	35.695	40.154	35.932	33.572
	tons/h	40.926	27.215	29.796	36.788	43.757	31.402	39.355	44.271	39.616	37.014
Nominal furnace capacity	Mg	121.5	121.6	121.6	121.6	121.6	121.6	121.6	121.6	121.6	
	tons	134	134	134	134	134	134	134	134	134	134
Shop effluent											
Flow rate	m^3/min	3,239	2,722	1,722	2,630	1,311	2,491	1,740	3,575	1,562	2,332
	acfm	114,460	96,200	60,845	92,933	46,314	88,011	61,468	126,322	55,212	82,418
	dscm/min	3,152	2,613	1,680	2,517	1,244	2,333	1,697	3,460	1,520	2,246
	dscfm	111,372	92,348	59,377	88,936	43,959	82,422	59,940	122,251	53,704	79,369
Flow rate per unit of furnace capacity[b]	dscm/min/Mg	--	--	--	--	--	--	--	--	--	--
	dscfm/ton	--	--	--	--	--	--	--	--	--	--
Temperature	°C	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9
	°F	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.2
Water vapor	% volume	0.2	0.5	0.0	0.3	0.4	0.0	1.2	1.3	0.9	0.5
CO	% volume	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
O_2 dry	% volume	19.4	19.4	18.3	19.2	17.8	17.5	18.3	19.9	20.0	18.9
CO_2 dry	% volume	1.0	1.0	1.8	0.8	2.5	2.5	1.3	0.6	0.2	1.3
Particulate matter emissions											
Concentration	mg/m^3	0.389	0.435	0.183	0.137	0.275	0.412	0.641	0.939	1.83	0.573
	gr/acf	0.00017	0.00019	0.00008	0.00006	0.00012	0.412	0.00028	0.00041	0.00080	0.00025
	mg/dscm	0.389	0.435	0.183	0.137	0.275	0.00018	0.664	0.962	1.88	0.595
	gr/dscf	0.00017	0.00019	0.00008	0.00006	0.00012	0.00018	0.00029	0.00042	0.00082	0.00026
Emission rate	kg/h	0.41	0.46	0.20	0.15	0.29	0.44	0.71	1.03	2.00	0.63
	lb/h	0.91	1.02	0.43	0.32	0.65	0.97	1.55	2.26	4.42	1.39
Emission factor[b]	kg/Mg	--	--	--	--	--	--	--	--	--	--
	lb/ton	--	--	--	--	--	--	--	--	--	--

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[a] Reference Test Method 5 data. Traversed across top of compartments.

[b] Twelve-compartment baghouse; three compartments tested. Flow rate per unit of furnace production and emission factor not calculated.

TABLE C-24. SUMMARY OF VISIBLE EMISSION DATA FROM DUST-HANDLING SYSTEMS AT EAF AND AOD VESSEL STEEL MILL FACILITIES[3,30,31,36]

Plant	Length of observations minutes	Maximum 6-minute average opacity, percent
B[a]	12	0.6
C	20	5.0
P[b]	594	0[c]
Q[d]	60	0[c]
Q[d,e]	48	7.3

[a] EAF fabric filter.

[b] EAF/AOD fabric filter.

[c] Reference Method 22 (no emissions were visible). The operation observed did not include the dust transfer from the storage silo to truck.

[d] AOD fabric filter.

[e] The operations observed included the dust transfer from the storage silo to truck.

C.5 REFERENCES FOR APPENDIX C

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3. Compliance Tests Under New Source Performance Standards: Florida Steel Corporation, Charlotte, North Carolina. Sholtes & Koogler, Environmental Consultants. Gainesville, Florida. January 1980.

4. Addendum No. 1, Compliance Tests Under New Source Performance Standards: Florida Steel Corporation, Charlotte, North Carolina. Sholtes & Koogler, Environmental Consultants. Gainesville, Florida. January 1980.

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9. Compliance Tests Under New Source Performance Standards: Florida Steel Corporation, Tennessee Mill Division, Jackson, Tennessee. Sholtes and Koogler. Gainesville, Florida. December 1981.

10. Particulate Emission Tests for Lukens Steel Electric Melt Shop. Fuller Company. Catusauqua, Pennsylvania. September 23, 1973.

11. Memo from Terry, W., Midwest Research Institute, to Iversen, R., EPA/ISB. September 3, 1980. Site visit report--Florida Steel Corporation, Charlotte, North Carolina.

12. Memo from Terry, W., Midwest Research Institute to Iversen, R., EPA/ISB. December 10, 1980. Site Visit Report--Hoeganaes Corporation, Gallatin, Tennessee.

13. Memo and attachments from Terry, W., Midwest Research Institute, to Iversen, R., EPA/ISB. January 6, 1981. Site visit report--North Star Steel, Monroe, Michigan.

14. Letter from Christiansen, J., Raritan River Steel Co., to Iversen, R. E., EPA/ISB. September 24, 1981. Response to request for information about the Perth Amboy, New Jersey, plant.

15. Telecon. Terry, W., Midwest Research Institute, to Bottoms, P., Nucor Steel. September 30, 1981. Information on control system and compliance test at the Jewett, Texas, plant.

16. Memo and attachment from Terry, W., Midwest Research Institute, to EAF files. May 17, 1982. Trip reports to Lukens Steel, Coatsville, Pennsylvania (August 1972), and Bethlehem Steel Corporation, Seattle, Washington (March 1973).

17. Memo from Banker, L., Midwest Research Institute, to Iversen, R., EPA/ISB. July 28, 1980. Source emission test observation report--Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

18. Letter and attachments from Lukas, A. W., J&L Steel Corporation, to Banker, L. C., Midwest Research Institute. March 2, 1981. Submission of compliance test report for J&L-Pittsburgh Works.

19. Visible Emission Data for J&L, Pittsburgh, Pennsylvania. Allegheny County Health Department. Pittsburgh, Pennsylvania. Undated.

20. Electric Arc Furnace Baghouse Compliance Test: Sharon Steel Corporation, Farrell, Pennsylvania, January 6, 7, and 8, 1981. WFI Sciences Company. Pittsburgh, Pennsylvania. WFI Sciences Report No. 8343.

21. Letter from Heintz, J. K., Sharon Steel Corp. to Iversen, R. E., EPA/ISB. February 2, 1981. Response to request for information about the Sharon, Pennsylvania, plant.

22. Memo and attachments from Terry, W., Midwest Research Institute, to Iversen, R., EPA/ISB. March 23, 1981. Source test report--Atlantic Steel, Cartersville, Georgia.

23. Letter from Hawkins, J. B., Atlantic Steel Company, to Iversen, R. E., EPA/ISB. April 13, 1981. Response to request for information about the Cartersville, Georgia, plant.

24. Memo and attachments from Banker, L., Midwest Research Institute, to Iversen, R., EPA/ISB. March 30, 1981. Source test report--U.S. Steel, Baytown, Texas.

25. Letter from Carnes, D. S., U.S. Steel, to Iversen, R., EPA/ISB. September 24, 1981. Response to request for information about the Baytown, Texas, plant.

26. Memo and attachments from Terry, W., Midwest Research Institute, to Pahl D., EPA/SDB. August 31, 1982. Source Test Trip Report--Chaparral Steel, Midlothian, Texas.

27. Memo and attachments from Banker, L., Midwest Research Institute, to Iversen R., EPA/ISB. March 26, 1981. Source Test Trip Report--Chaparral Steel, Midlothian, Texas.

28. Letter from Nicholson, W. T., Chaparral Steel, to Iversen, R., EPA/ISB. December 3, 1981. Response to request for information about the Midlothian, Texas, plant.

29. Memo and attachment from Banker, L., Midwest Research Institute, to Iversen, R., EPA/ISB. June 3, 1981. Source Test Report--Bethlehem Steel, Los Angeles, California.

30. Emission Test Report: AL Tech Specialty Steel Corporation, Watervliet, New York. EPA/EMB No. 80-ELC-7. July 1981.

31. Emission Test Report: Carpenter Technology Corporation, Reading, Pennsylvania. PEDCo Environmental, Inc. Cincinnati, Ohio. Contract No. 68-02-3546, Work Assignment No. 2. July 1981.

32. Memo and attachment from Maxwell, W. H., Midwest Research Institute, to EAF files. August 18, 1981. August 1978 source test report for the CarTech-Reading facility.

33. Letter and attachments from Geiser, L. H., Carpenter Technology Corporation, to Banker, L. C., Midwest Research Institute. January 30, 1981. Submission of test data for Bridgeport and Reading, Pennsylvania, shops.

34. Memo and attachments from Terry, W., Midwest Research Institute, to Iversen, R., EPA/ISB. May 8, 1981. Source test observation report--AL Tech Specialty Steel Company, Watervliet, New York.

35. Memo and attachments from Terry, W., Midwest Research Institute, to Iversen, R., EPA/ISB. May 18, 1981. Source test observation report--Carpenter Technology Corporation, Reading, Pennsylvania.

36. Visible Emission Summary Report for Carpenter Technology Corporation, Reading, Pennsylvania. PEDCo Environmental, Inc. April 1982.

37. Memo and attachments from Banker, L., Midwest Research Institute, to Iversen, R., EPA/ISB. December 28, 1980. Source test observation report--Eastern Stainless Steel Company, Baltimore, Maryland.

38. Visible Emission Survey Report: Eastern Stainless Steel Company, Baltimore, Maryland. PEDCo Environmental, Inc. Cincinnati, Ohio. Contract No. 68-02-3546, Work Assignment No. 2. December 1980.

APPENDIX D

EMISSION MEASUREMENT AND CONTINUOUS MONITORING

D.1 EMISSION MEASUREMENT METHODS

Particulate matter emissions from electric arc furnaces (EAF's) and argon-oxygen decarburization (AOD) vessels were measured at two specialty steel mills. At Plant P the emissions from two EAF's and two AOD vessels were ducted to a single positive-pressure fabric filter (PPFF). At Plant Q the emissions from a single AOD vessel were routed to one PPFF. Both controlled and uncontrolled emissions of particulate matter were measured simultaneously at each plant.

Because the multiple-furnace arrangement at Plant P precluded testing for an integral number of heats at all sites, representative operation of all four units was used as the testing guideline. Tests were interrupted if one of the EAF's experienced an operational delay of longer than 20 minutes. Periods of no production that lasted from 1 to 1.5 hours were tolerated for the AOD vessels, because that amount of downtime normally occurred at this plant when an AOD vessel was waiting for the next metal charge from an EAF.

At Plant Q the significance of testing for an integral number of heats was minimized by the large number of heats sampled (approximately five heats per run). Also, because the interval between heats was short (between 5 and 10 minutes), sampling continued until all traverses were completed and was not interrupted except for port changes, AOD vessel operational delays, and incidents of unrepresentative conditions.

Visible emissions at the control device outlet and the melt shop roof were determined at Plants P, Q, and S and at four carbon steel shops (Plants L, M, N, and O). Visible emissions from the melt shop roof also were determined at Plant J.

Fugitive emissions from dust handling systems were evaluated at Plants P, Q, and J.

The following sections describe the methods used to measure particulate matter at all inlet sites and the outlet at Plant Q, modifications made to EPA Reference Method 5* for testing the PPFF outlet at Plant P, and the methods used to determine visible emissions. The last section discusses the selection of methods.

D.1.1 Reference Methods

Environmental Protection Agency Reference Methods 1, 2, 3, and 5* were used to measure volumetric flow rates and particulate emissions at the inlet sites at both plants and the outlet sites at Plant Q.

Sampling points were located in the duct cross sections according to Method 1, except in the case of the inlet site at Plant Q, which did not meet minimum specifications for distance from flow disturbances. This site was considered to be acceptable for sampling after an evaluation of the velocity profile and a comparison of measured flows with design flows.

A "type-S" pitot tube and an inclined draft gauge manometer were used to measure the gas velocity pressures at each sampling point across the duct (according to the procedures outlined in EPA Reference Method 2) to determine an average value. A thermocouple and potentiometer were used to measure the temperature at each sampling point.

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*40 CFR 60, Appendix A, July 1, 1980.

Flue gas composition was determined by the procedures described in EPA Reference Method 3. Integrated bag samples of gas collected during preliminary runs were analyzed for oxygen and carbon dioxide by use of an Orsat Gas Analyzer. Since these results verified that the gas streams were essentially air, additional samples were not collected.

Reference Method 5 was used to measure particulate concentrations. Tests were conducted isokinetically by traversing the cross-sectional area of the stack and regulating the sample flow rate relative to the gas velocity in the duct as measured by the pitot tube and thermocouple attached to the sample probe. The Plant Q outlet sampling train (shown in Figure D-1) consisted of a heated, glass-lined probe, heated 87-mm (3-in.) diameter glass fiber filter (Gelman Type AE), and a series of Greenburg-Smith impingers followed by an umbilical line and metering equipment. The inlet sampling train (shown in Figure D-2) was similar except that the probe was lined with 316 stainless steel and a Teflon sample line was used between the filter and first impinger. At the end of each test, the nozzle, probe, and filter holder portions of the sample train were acetone-rinsed. The acetone rinse and filter media were dried at room temperature, desiccated to a constant weight, and weighed on an

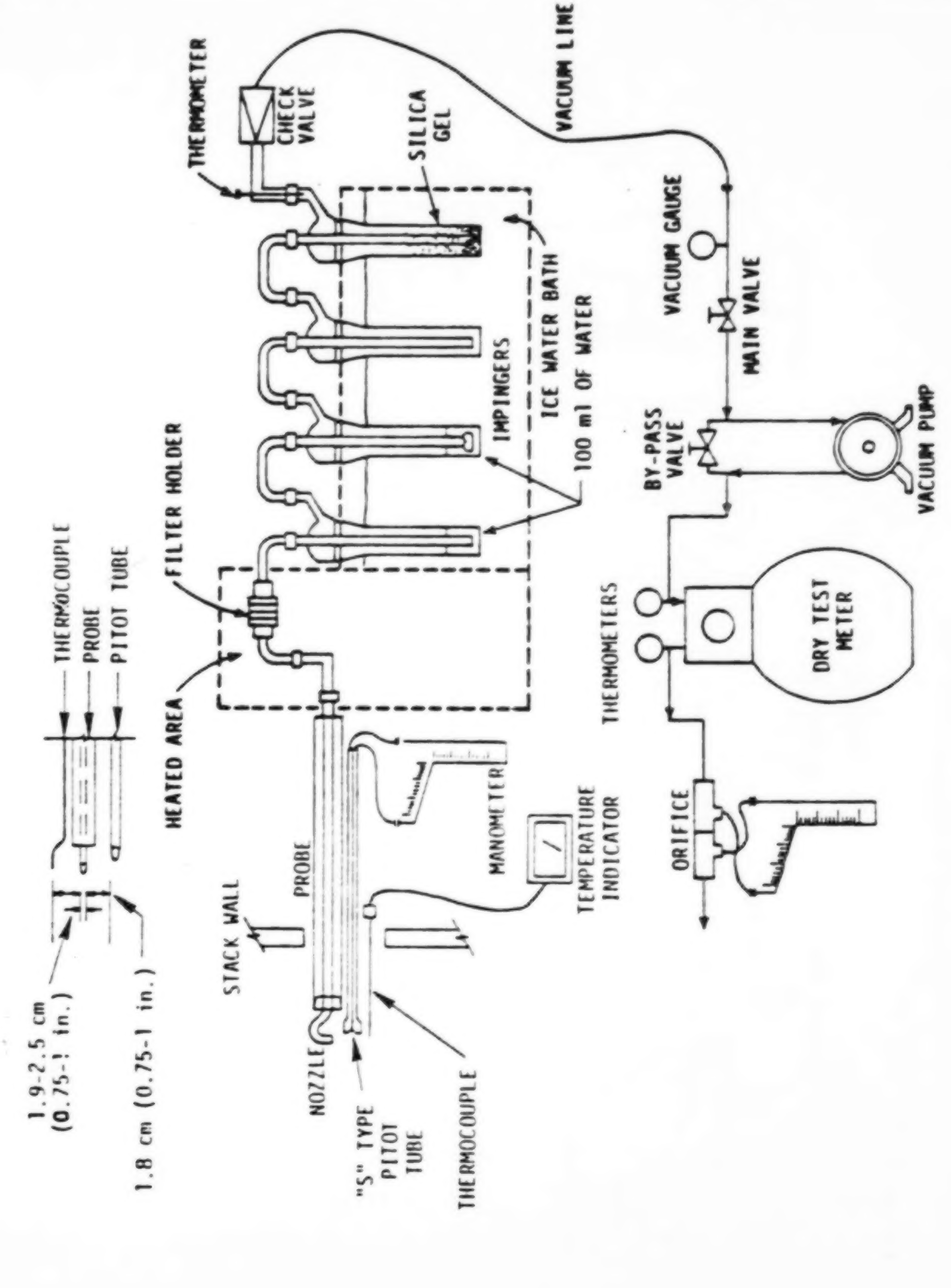
1.9-2.5 cm
(0.75-1 in.)
1.8 cm (0.75-1 in.)
THERMOCOUPLE
PROBE
PITOT TUBE
NOZZLE
"S" TYPE PITOT TUBE
THERMOCOUPLE
STACK WALL
PROBE
HEATED AREA
FILTER HOLDER
MANOMETER
TEMPERATURE INDICATOR
IMPINGERS
100 ml OF WATER
ICE WATER BATH
SILICA GEL
THERMOMETER
CHECK VALVE
VACUUM LINE
ORIFICE
THERMOMETERS
DRY TEST METER
BY-PASS VALVE
VACUUM PUMP
MAIN VALVE
VACUUM GAUGE

Figure D-1. Particulate sampling train at Plant Q outlet.

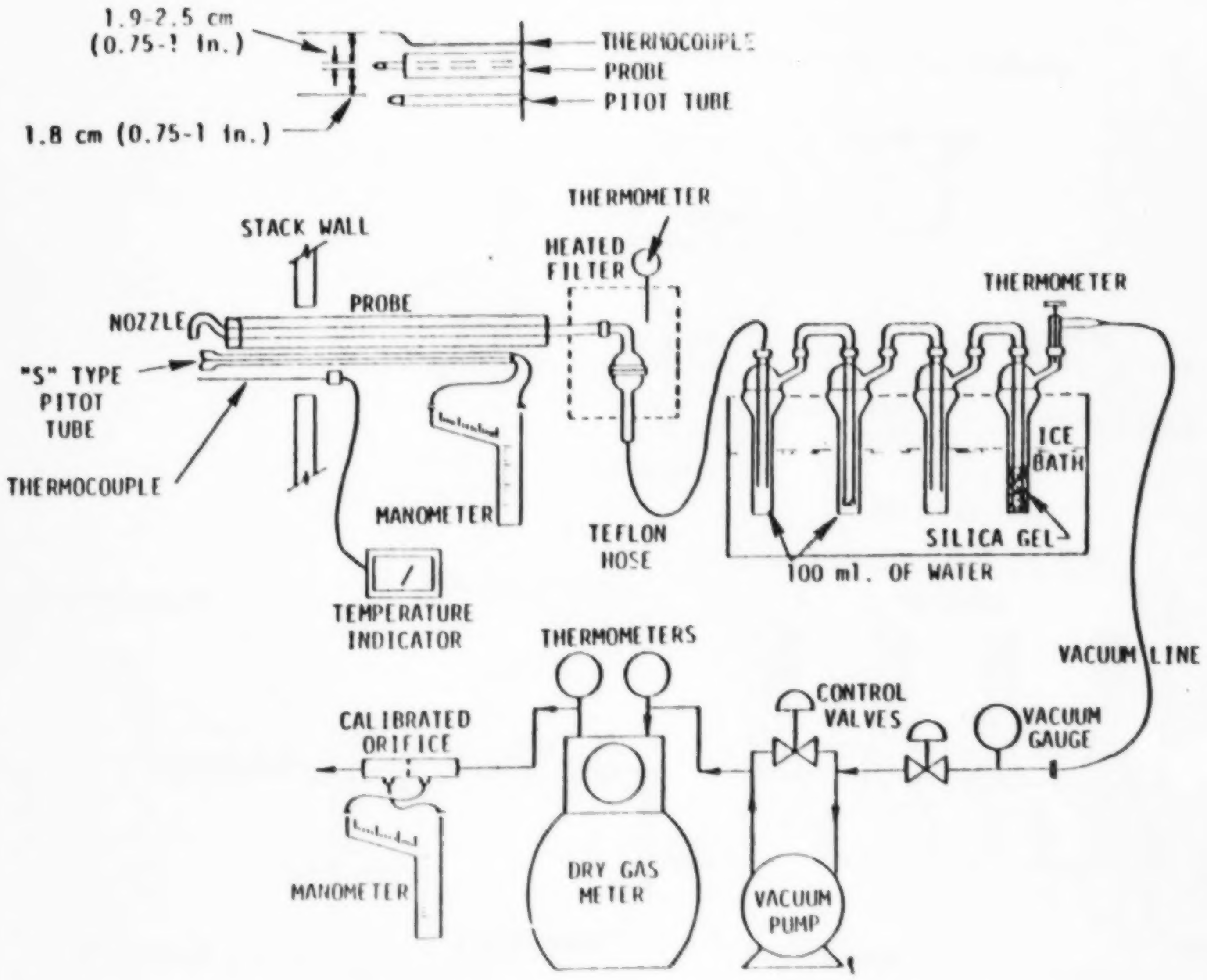
1.9-2.5 cm
(0.75-1 in.)
1.8 cm (0.75-1 in.)
THERMOCOUPLE
PROBE
PITOT TUBE
STACK WALL
THERMOMETER
HEATED
FILTER
PROBE
NOZZLE
"S" TYPE
PITOT
TUBE
THERMOCOUPLE
MANOMETER
TEMPERATURE
INDICATOR
TEFLON
HOSE
THERMOMETER
ICE
BATH
SILICA GEL
100 ml. OF WATER
VACUUM LINE
THERMOMETERS
CONTROL
VALVES
VACUUM
GAUGE
CALIBRATED
ORIFICE
MANOMETER
DRY GAS
METER
VACUUM
PUMP

Figure D-2. Particulate sampling train at Plant A and Q inlets.

analytical balance. Total filterable particulate matter was determined by adding the net weights of the two sample fractions. The amount of water collected in the impinger section of the sampling train was measured (any condensate in the sample line used at the inlet was first drained into the impingers). The impinger contents of the Plant Q outlet train were recovered and analyzed for organic and inorganic condensible matter by ether-chloroform extraction.

The outlet site at Plant Q consisted of five stacks, which were all traversed during each particulate test run. The actual minimum sampling time and volume for these tests were 8 hours and 10.8 dscm (380 dscf), which exceeded the respective minimum requirements of 4 hours and 4.5 dscm (160 dscf) specified for EAF's in Subpart AA of the Federal Register.*

D.1.2 Modified Reference Methods

Controlled emissions at Plant P exited a fabric filter through a top-mounted monovent in a configuration typical of PPFF's. This exhaust configuration required that several modifications be made to EPA reference methods so they could be used in the outlet tests.

Figure D-3, a top view of the fabric filter arrangement, shows the general location of sampling points. Figure D-4, an end view of the fabric filter, shows the location of the sampling plane used in each compartment with respect to the site configuration.

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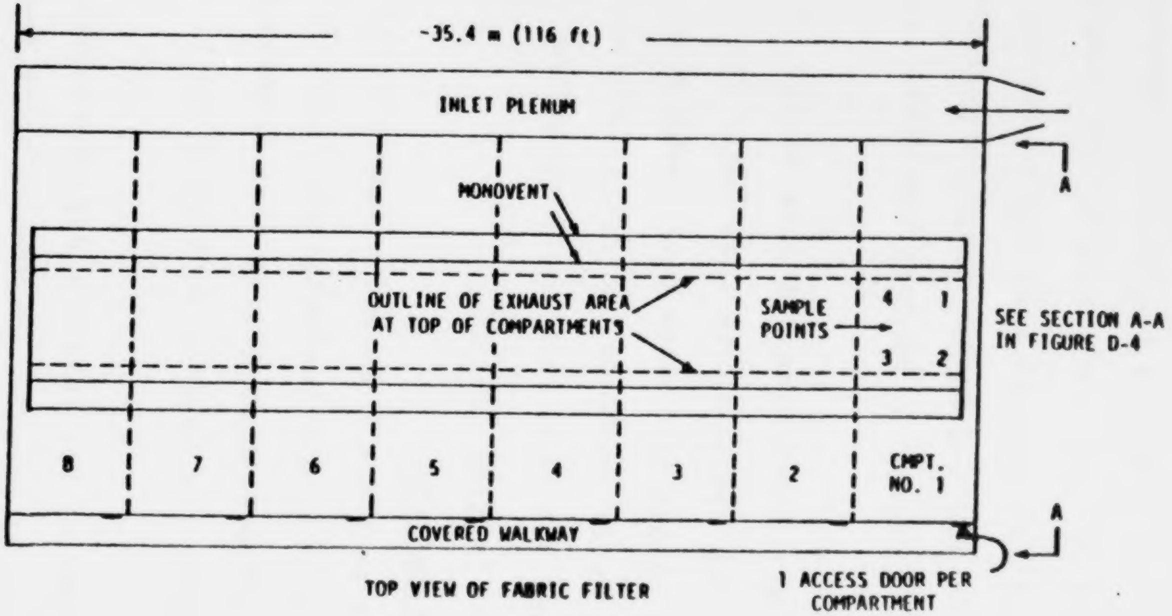
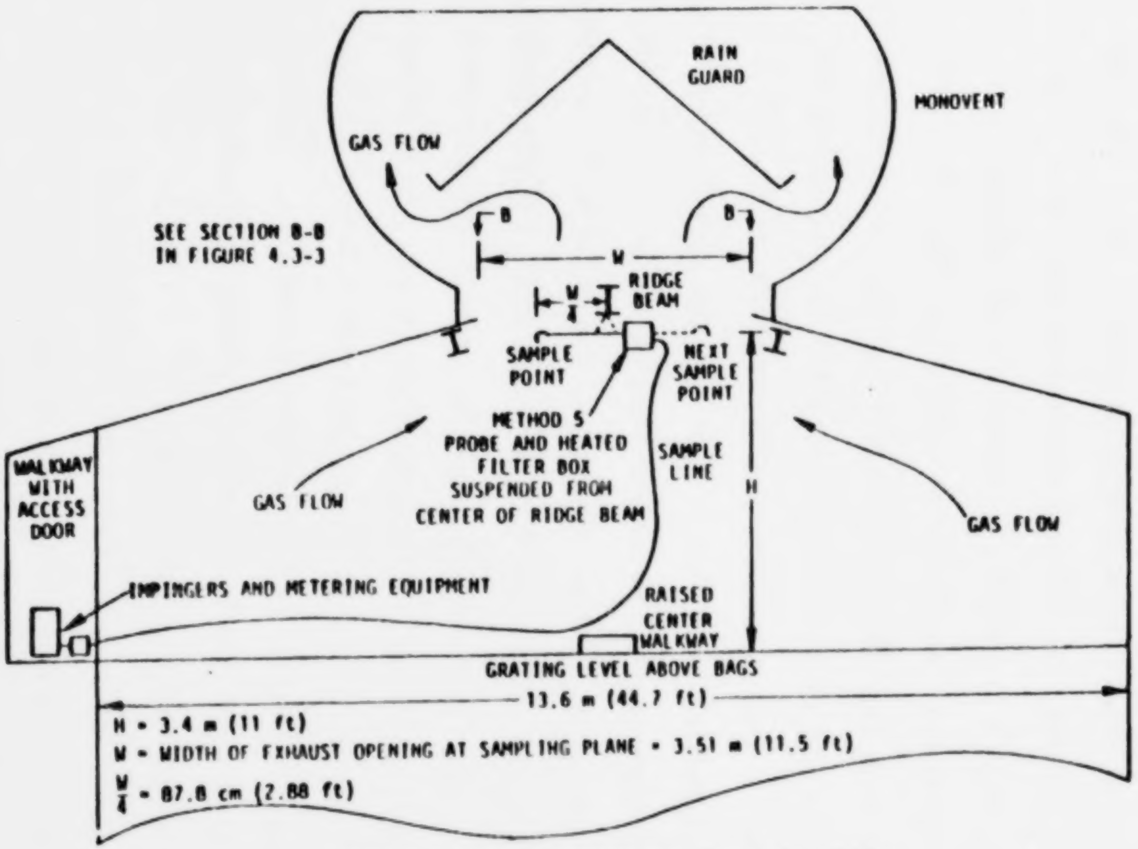
*40 CFR 60, Subpart AA, July 1, 1980.


~35.4 m (116 ft)
INLET PLENUM
MONOVENT
OUTLINE OF EXHAUST AREA
AT TOP OF COMPARTMENTS
SAMPLE
POINTS
4
1
3
2
SEE SECTION A-A
IN FIGURE D-4
A
A
8
7
6
5
4
3
2
CMPT.
NO. 1
COVERED WALKWAY
TOP VIEW OF FABRIC FILTER
1 ACCESS DOOR PER
COMPARTMENT

RUN 1 - COMPARTMENT NOS. 1 THROUGH 4
RUN 2 - COMPARTMENT NOS. 3 THROUGH 6
RUN 3 - COMPARTMENT NOS. 5 THROUGH 8

Figure D-3. Fabric filter outlet at Plant P.


RAIN GUARD
MONOVENT
GAS FLOW
SEE SECTION B-B IN FIGURE 4.3-3
B
B
W
$\frac{W}{4}$
RIDGE BEAM
SAMPLE POINT
NEXT SAMPLE POINT
METHOD 5 PROBE AND HEATED FILTER BOX SUSPENDED FROM CENTER OF RIDGE BEAM
SAMPLE LINE
H
WALKWAY WITH ACCESS DOOR
GAS FLOW
GAS FLOW
IMPINGERS AND METERING EQUIPMENT
RAISED CENTER WALKWAY
GRATING LEVEL ABOVE BAGS
13.6 m (44.7 ft)
H = 3.4 m (11 ft)
W = WIDTH OF EXHAUST OPENING AT SAMPLING PLANE = 3.51 m (11.5 ft)
$\frac{W}{4}$ = 87.8 cm (2.88 ft)

SECTION A-A, FABRIC FILTER END VIEW FACING SOUTH

Figure D-4. Sampling location at the fabric filter outlet at Plant P.

Reference Method 5 equipment and modified sampling procedures were used. The sampling train was similar to those used at the inlet sites (shown in Figure D-2) except for the lack of a pitot tube and the use of a glass-lined probe. Tests were conducted at a constant sampling rate based on the estimated average velocity of the entire sampling area. This average velocity was calculated by first converting the total flow rate measured at the inlet to outlet conditions of temperature, pressure, and moisture, and then dividing by the total outlet sampling area. The resultant average velocity was assumed to represent each sampling point and was used to calculate an average isokinetic sampling rate. The heated probe and filter assembly was suspended from the center of the ridge beam in a fabric filter compartment, as shown in Figure D-4. The nozzle was positioned at each of the four sampling points in a compartment by rotating the probe and filter assembly. Compartment cleaning cycles were sampled as they occurred. Compartment gas flows were interrupted while test equipment was moved from one compartment to another, but conditions were allowed to equilibrate for several minutes before sampling resumed. Outlet samples were recovered and analyzed in a manner identical to that used for inlet particulate samples.

As shown in Figure D-3, four compartments were sampled per run. By the end of three runs, each compartment had been tested at least once. The actual minimum sampling time and volume were 5.3 hours and 5.9 dscm (208 dscf), which exceeded the respective minimum requirements of 4 hours and 4.5 dscm (160 dscf).

D.1.3 Visible and Fugitive Emission Methods

Certified observers recorded visible emissions from melt shop roofs and fabric filter exhausts according to procedures described in EPA Method 9.* Data were taken in 6-minute sets, and individual readings were recorded in percent opacity at 15-second intervals. Intermittent rest periods were taken to prevent eye fatigue; however, as long as emissions were visually detectable, readings were continued until a break was absolutely necessary. The emission points were casually monitored during break periods, and readings were resumed if emissions greater than zero opacity were noticed.

In most cases the configuration of melt shop roofs and fabric filter exhausts presented a potentially large area in which visible emissions could occur. These large areas were separated into two or more smaller segments that were labeled and simultaneously observed. Then, the magnitude of any emissions that were visible during the observation period was matched with the segment from which they were emitted. This procedure facilitated data collection and comparison of emissions with furnace operations.

The opacity data typically represent visible emissions emanating from an area much smaller than the total potential exhaust area. For example, at one plant melt shop emissions escaped through an opening in the side of the building. The average opacity recorded on the data sheet represented that small area, not what the average opacity would have been for the entire melt shop. Another example would be the typical long and narrow exhaust of a PPFF. Emissions from the entire exhaust might be 0 percent opacity until a compartment cleaning cycle occurs. At that time the opacity from one-tenth (for a 10-compartment baghouse) of the exhaust area may be 5 percent opacity while the rest is 0 percent. The recorded opacity would be 5 percent.

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*40 CFR 60, Appendix A, July 1, 1980.

Because the intent was to record only emissions directly related to operation of the furnaces being evaluated, visible emissions from nearby furnaces or casting areas were disregarded with the aid of a process observer inside the melt shop. Visible emission data at Plants P and Q were obtained simultaneously with those for particulate matter tests.

Fugitive emissions from fabric filter dust-handling systems at Plants P and Q were observed according to proposed Method 22.* Emissions were recorded as the cumulative amount of time during a 20-minute observation period that any fugitive emissions were visually detectable. Between three and thirty observation periods were recorded during each test series.

Emissions from the dust-handling systems at Plants Q and J were observed according to EPA Method 9 by a certified observer. A visual inspection was made of the dust hoppers beneath the main fabric filter(s) and the ductwork associated with the pneumatic transfer system while dust was being transferred from the hoppers to the storage bin. No fugitive emissions were visually detected in these systems at either plant. Between two and six 6-minute sets of visible emission data were then recorded at the outlet of the small fabric filter controlling emissions from the pneumatic transfer system. Between two and eight 6-minute sets were recorded during the transfer of dust from the storage bin to a truck. Individual opacity readings were taken at 15-second intervals. The amount of data collected was dependent on the length and frequency of the different operations.

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*Federal Register, Vol. 45, No. 224, November 18, 1980.

D.1.4 Discussion of Methods Selected

The inlet sites at Plants P and Q and the outlet site at Plant Q were amenable to sampling by EPA Reference Methods 1, 2, 3, and 5; therefore, these methods were selected. Long sample times and large sample volumes were used for the outlet tests to minimize potential sample handling and weighing errors caused by low particulate loadings.

The outlet site at Plant P was not directly amenable to sampling by EPA Reference Methods 1, 2, and 5. In the past, a typical approach to sampling PPFF's has been to use high-volume (hi-vol) type samplers. In general, particulate concentration data obtained from EAF installations by hi-vol techniques are lower than concentrations measured by Method 5 at similar installations. Specifically, a comparison of particulate concentrations obtained simultaneously at one plant by a hi-vol technique and a modified version of Method 5 indicated that the average hi-vol particulate concentrations were less than 20 percent of the corresponding modified Method 5 results.[1,2] Because of this apparent unresolved discrepancy, the use of a modified Method 5 was preferable to any hi-vol technique for obtaining emission data that might be used in the standard setting process.

The modified test methods used at Plant P, which generally would apply when testing PPFF's without stacks, are discussed in the following sections.

Although they could not be analyzed precisely, the effects of method variations on outlet particulate concentration results at Plant P were considered to be relatively minimal. The two deviations from Method 1 were the use of a sampling location less than two equivalent duct diameters downstream from the nearest disturbance and sampling at fewer than the minimum number of points. The three deviations from Method 5 were the lack of velocity monitoring at individual sampling points, the use of a constant sampling rate at all points during a given test, and the traversing of only half of the large exhaust area for each test.

The outlet site configuration offered no sampling location capable of meeting minimum Method 1 criteria. Therefore, the throat of the monovent was chosen as an optimum sampling location because it represented the smallest cross-sectional area.

This small area would not only provide the highest gas velocities, but also offer less chance for bias due to faulty bags. Sampling at the selected location was supported by a previous independent study.[3]

Because moving from one traverse point to another during sampling required test personnel to enter a compartment while the fabric filter was operating, extraneous dust could have been stirred up by the accidental bumping of the probe against nearby beams or by personnel activity, and results could have been biased if this dust had entered the nozzle during sampling. Therefore, only four sampling points per compartment were used so as to lessen the possibility of biasing results. The sampling of only four compartments and the use of extreme care during point changes precluded the occurrence of these potential problems in all of the tests.

A better sampling approach for this type of fabric filter configuration would be to sample from the outside (on the baghouse roof) and to use ports located in the monovent throat. This would reduce the possibility of sampling extraneous dust and shorten the time required to change traverse locations. More points and compartments per run could then be sampled. Because safe access to the roof was not readily available, such ports were not installed at Plant P.

A constant sampling rate was used because accurate measurements could not be taken of individual point velocities to make isokinetic sampling rate adjustments. The preliminary traverse verified the inaccuracy of velocity measurement attempts. Thus, the average velocity at the outlet sampling location was calculated by the use of measured inlet data (assuming no air leakage).

At Plant P the inlet and outlet tests were conducted simultaneously. Therefore, previously measured inlet velocity data were used to estimate an average velocity for each outlet test. Measured data from the simultaneous inlet tests were later used to calculate real average velocities.

As previously stated, the conversion of inlet flow to outlet flow assumed no air leakage. At Plant P there were two sources of air inleakage: the induced draft fans and the open gratings at the bottom level of the fabric filter. A comparison of measured versus design flow indicated that the leakage at the fans was minimal. Entry of dilution air through the open grating was minimized by covering the openings during the tests. In as much as a significant inflow of ambient air would have caused a temperature decrease, the close agreement between inlet and outlet gas temperatures indicated that any entry of dilution air was negligible.

The average isokinetic sampling rates indicated for the outlet tests at Plant P were all within the acceptable range (100 ± 10 percent). Several factors and assumptions affected these isokinetic rate calculations: the inlet flow equaled the outlet flow (previously discussed); the effect of fabric filter cleaning cycle time and frequency on average outlet velocity could be calculated; the average velocity for the four compartments sampled per run was approximately equal to the average velocity for all eight compartments; and the average velocity at each traverse point was approximately equal to the overall average velocity. As discussed in the following paragraphs, it is believed that these factors were satisfactorily resolved.

The effect of the fabric filter cleaning cycle could be determined by first calculating the fraction of time that a compartment was on line, and then multiplying this fraction by the total exhaust area to determine the average effective exhaust area and the corresponding average effective exhaust velocity.

The average velocity for the four compartments sampled per run should have been reasonably close (±10 percent) to the average velocity for all eight compartments, even if the gas flow was not evenly distributed between all of the compartments. This is because each sample run included half of the total number of compartments.

Although average outlet isokinetic rates were acceptable, local gas velocities could have influenced values at individual traverse points and the results could have been much different. The range of actual velocity variation was difficult to gauge without valid point data; however, the overall isokinetic rates were within specified limits, and any point-specific biases should tend to be averaged.

In summary, the results of the modified Method 5 tests at the Plant P outlet site were fairly consistent and appeared to be representative. It is believed that Method 5 equipment can be used to yield acceptable particulate concentration results at sites that do not meet Method 1 criteria and where point velocities cannot be accurately measured. The precision of a method using a constant sampling rate could be less than that of Method 5, which requires isokinetic sampling at each point.

D.2 MONITORING SYSTEMS AND DEVICES

D.2.1 Opacity Monitoring

Transmissometers suitable for continuously monitoring the opacity of a confined gas stream, such as in the exhaust stack of a suction-type fabric filter, are readily available. A complete continuous opacity monitoring system (COM) is described by Performance Specification 1 (PS-1) in Appendix B of the *Federal Register*.* In a case where condensed moisture would be present in the gas stream, such as after a wet scrubber, a COM would not be applicable; therefore, another operating parameter would need to be monitored as an indication of emissions.

Equipment and installation costs for a COM meeting the requirements of PS-1 are estimated to be approximately $30,000 per unit, including the cost of the initial Performance Specification Test. Annual operating costs are estimated to be approximately $10,000 per unit including data handling, but not including any reporting requirements.

Currently available COM's have not proven to be effective when applied to exhaust gas streams from PPFF's typically used at EAF and/or AOD vessel installations. Since PPFF's frequently have multiple exhaust points, COM's would have to be installed at each point, thereby greatly increasing capital and annual costs. The other frequent type of PPFF exhaust configuration is a long, narrow vent. There are several technical problems associated with positioning a single COM to monitor several small emission points or one long emission path. These include:

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*40 CFR 60, Appendix B, July 1, 1980.

1. The narrow path of the COM measurement beam does not always cover a representative portion of the fabric filter emissions. Stratification of particulate emissions can occur when bags leak or tear, causing a significant increase in localized opacity. However, because of stratified flow, the gas stream with increased opacity may not intercept the path of COM measurement beam.

2. The signal response of the COM measurement beam crossing the exhaust of many fabric filter compartments is relatively insensitive to the performance of any individual fabric filter compartment. A significant emissions increase from a single compartment due to an equipment failure may appear as only a small increase in the opacity signal of a COM that has a long measurement path and may not be sufficient indication to plant personnel that additional maintenance is required.

3. The opacity standard is based on emissions from much shorter path lengths than the lengths of many roof monitors, requiring a correction factor for the COM to relate the long path COM reading to the emission standard. The correction factor magnifies the deficiency described in Item 2.

4. Unless the COM measurement beam is enclosed in the spaces between multiple emission points, interference from the ambient air (e.g., dust, fog) can indicate higher emissions than are actually present in the exhaust gas stream.

Thus, a COM may not be a reliable indicator of good emissions control and proper operation and maintenance techniques when used on a PPFF that does not have a single discharge stack. However, Reference Method 9 measurements can be made by certified plant personnel in lieu of COM data where PPFF's without single stacks are used.

The approach would require that a visible emissions observer walk the length of the fabric filter and briefly observe the emissions from each compartment or exhaust to determine if emissions occur. If emissions do occur, the observer would conduct a longer-term visible emission test of the specific exhaust(s) to document the magnitude of emissions.

The walk-through observation would be required once per day (five times per week) during the melting and refining phase of a heat cycle. Three 6-minute periods of observation would be required for each emission point exhibiting visible emissions. This approach is based on the concept that minor fabric filter malfunctions generally manifest themselves gradually.

The preceding paragraphs on technical problems associated with COM's on PPFF's and the proposed use of daily Method 9 observations in place of a COM are based on EPA analysis discussed in an EPA report.[4]

The annual cost of an approach using daily Method 9 observations is estimated to be approximately $5,000 per control device, including the cost of observer certification.

D.2.2 Flow Monitoring Systems

Subpart AA contains several continuous flow monitoring requirements for EAF emission capture systems: the flow in each separately ducted emission capture hood must be monitored; the internal static pressure of the furnace free space must be monitored when process emissions are captured by a direct shell evacuation control (DEC) system; and no monitoring is necessary on systems that capture all emissions (i.e., building evacuation).

These monitoring requirements were included in Subpart AA as an enforceable means of ensuring good capture of EAF emissions. The originally proposed concept of imposing opacity limits for visible emissions from melt shops was considered to be unenforceable, principally because of problems associated with multifurnace shops. The monitoring provisions were intended to work in the following way. The source was initially required to demonstrate that its emission capture system effectively captured EAF emissions during all phases of operation. As an example, this might mean that "X" amount of flow was required at Hood A and "Y" amount was needed at Hood B during the melt phase. During tapping or charging operations, the capture system might have to be adjusted so that 0.5X amount of flow was required at Hood A and 3Y was needed at Hood B. These flow adjustments would usually be made by changing various damper positions and maintaining constant fan conditions. Once the emission capture system was operating effectively, the various flow rates required in each hood during each phase of operation would be measured (e.g., X, 0.5X, Y, 3Y). Velocity probes would then be installed in appropriate ducts, and one or more recorders would be used to provide continuous output of the flow in each hood. Anytime the monitoring system indicated a flow rate less than the predetermined amount required for effective capture of emissions, operation could be deemed to be unacceptable.*

Since the promulgation of Subpart AA, compliance with the flow and pressure monitoring provisions therein has been attempted in several different ways. One plant has a simple system that records static pressure in the combined duct of an emission capture system consisting of a DEC and canopy hood ducted to one control device. Another plant has velocity probes in three of four separate ducts that continuously record flow rates. Other EAF installations have tried various combinations of duct static pressures, fan amperages, damper position indicators, and furnace mode indicators. Some sources have used such systems for local monitoring requirements or simply to ensure proper operation of the capture system.

Three general approaches to satisfying the intent of the flow monitoring requirements are discussed: 1) periodic operational status inspections, 2) monitoring of system parameters (other than velocity), and 3) flow monitoring. These discussions are followed by a discussion of performance specifications, costs, and availability of equipment for the different approaches.

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*Federal Register, Vol. 40, No. 185, pp. 43851-43852, September 23, 1975.

A simple means of monitoring the operation of an emission capture system is to use periodic operational status inspections. This approach is based on two premises: 1) most emission capture systems that need to alternate air flow between one or more hoods (or DEC ducts) will have a microprocessor or equivalent set up to make appropriate damper adjustments (automatically or semiautomatically) according to furnace mode, and 2) normal operation of an emission capture system should not vary except during maintenance or equipment malfunctions. Initial demonstration of effective capture would still be required. At that time the various combination of operating parameters (e.g., damper position, fan amps, furnace static pressure) that produced effective capture would be recorded. Periodic (e.g., monthly) inspections of the system would include giving specific attention to these parameters.

The second approach to flow monitoring actually consists of two alternatives. The first alternative includes maintaining a log of key operating parameters (e.g., damper position, fan amps, furnace static pressure) on a once-per-shift basis. This would essentially be a more frequent operational-status inspection (as just described). The second alternative would include recording these key parameters on strip charts so they could be compared with initial values. This entire second approach is based on the concept that the effectiveness of the emission capture system can be evaluated by observing parameters that are either indicative, proportional, or correlated to flow, as opposed to actually measuring flow.

The third approach would involve installation of velocity probes and chart recorders, which is essentially the same as what is currently required by Subpart AA.

Only the third approach would require any type of performance specification. The monitoring provisions of Subpart AA include several general equipment specifications, but no applicable Performance Specification is included in Appendix B of the Federal Register.* The EPA is in the process of developing a draft version of a Performance Specification applicable to flow monitoring systems. Although intended for use specifically on the emission control systems of basic oxygen furnaces, the specification should be generally applicable to any flow monitor now required by other New Source Performance Standards (NSPS). Therefore, an additional Performance Specification especially for EAF's is not necessary.

No additional equipment would be required for the periodic operational status inspections. The annual cost of monthly inspections is estimated to be $600 per furnace.

No additional equipment would be needed to maintain logs of key operating parameters because these parameters will have indicators already. The annual cost of maintaining once-per-shift logs is estimated to be no more than $13,000 per furnace or ressel.

The costs of the monthly operational status inspections or once-per-shift parameter logs can be absorbed by plant operating budgets with little or no impact because the work can be done without hiring additional personnel.

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*40 CFR 60, Appendix B, July 1, 1980.

Recorders are readily available for continuous monitoring of operating parameters. Assuming two multipoint recorders would be needed per furnace, equipment costs are estimated to be $6,000, including installation. Annual operating and maintenance costs, including data handling, are estimated to be $25,000 per furnace.

Velocity probes suitable for use in EAF emission capture systems are readily available. Operational history of velocity monitoring systems on EAF's appears to be limited, but probes from at least two different manufacturers have been used with relative success. One plant indicated that two of three probes (multi-point, averaging pitot tubes) used in a system that had been operating for 2 years required monthly cleaning, whereas the third probe needed cleaning every two weeks. Another plant using a different type of velocity device (continuous purge pitot tube) had been using two probes for over a period of a year with minimal attention. The reliability of a third type of velocity probe (heavy duty anemometer) has not been demonstrated on EAF's, but there is evidence to indicate that it should be suitable for this application without requiring more than monthly cleaning.

A typical EAF and/or AOD vessel installation is estimated to require either two or three velocity probes and one or two multipoint strip chart recorders per furnace. Equipment and installation costs (including the initial Performance Specification Test) would be between $15,000 and $20,000 depending on the number and type of devices selected. Annual operating and maintenance costs would be between $25,000 and $30,000 per furnace, with the major portion of these costs applied to operation and data handling. Equipment costs were obtained from vendors or vendor catalogs; installation costs are based on the work being done by plant personnel; and operating and maintenance costs are based on comments from several users.

D.3 PERFORMANCE TEST METHODS

Reference Method 5 is recommended for determining particulate concentration at any type of control device outlet capable of providing a sampling site that meets minimum Reference Method 1 criteria (e.g., a single or multiple stack that is more than 2.5 duct diameters long).

At other sites (e.g., PPFF's with monovents, ridge vents, or stub stacks less than 2.5 duct diameters long), proposed Reference Method 5D is preferred over any type of hi-vol technique. It may be necessary to determine specific modifications on a case-by-case basis, depending on the particular facility. The procedures discussed in Sections D.1.2 and D.1.4 can be used as guidelines for alternative procedures.

Reference Method 9 can be used to determine visible emissions from melt shops, control device outlets, and dust handling equipment. These methods are consistent with the methods used to gather emission data for the development of this document.

Subpart A of the Federal Register* requires (emphasis added) that facilities subject to NSPS be constructed so as to provide sampling ports, platforms, access, and utilities to conduct performance tests by the designated methods. It is recommended that these details be discussed by the plant and appropriate control agency during permit application prior to construction to avoid costs of retrofitting.

Depending on the site configuration, a performance test consisting of three Method 5 or Method 5D sampling runs on one control system may require between 4 and 8 man-days of field work. Total cost of an initial performance test on one control system is estimated to range from $5,000 to $8,000 including the test report.

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*40 CFR 60, Appendix A, July 1, 1980.

REFERENCES

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2. MMT Environmental. Compliance on a Baghouse at Raritan River Steel. Report No. 0302, June 18, 1980.

3 Fluidyne Engineering Corporation. Effective Sampling Techniques for Particulate Emissions From Atypical Sources. Prepared for U.S. Environmental Protection Agency under Contract No. 68021796. EPA 600/2-80-034, January 1980.

4. U.S. Environmental Protection Agency. Emission Standards and Engineering Division Recommendations for Emission Measurement of Positive Pressure Baghouses. Prepared by Peter Westlin, December 1981.